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REPORT OF THE INTERNATIONAL ICE PATROL SERVICE IN THE NORTH ATL--ETC(U)
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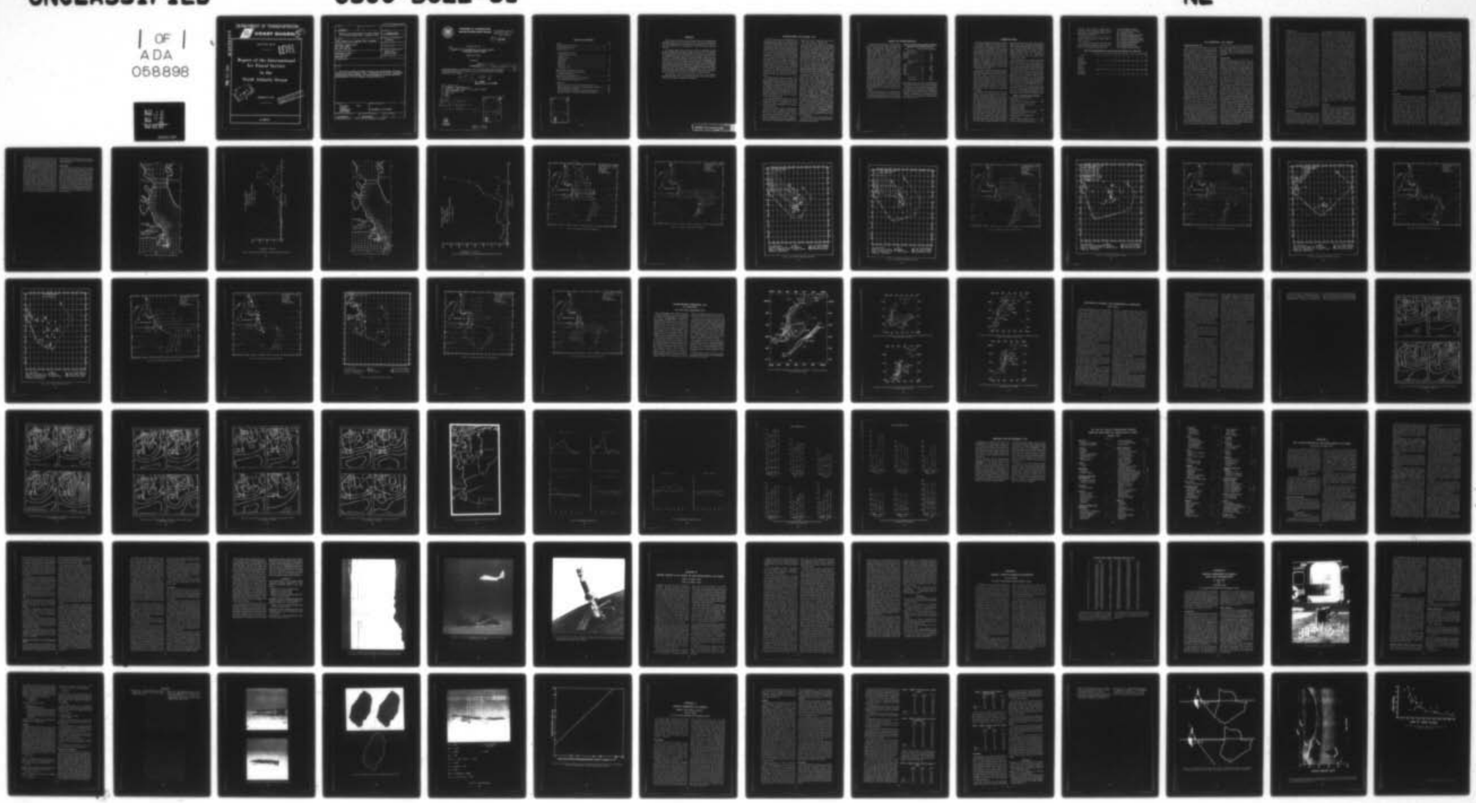

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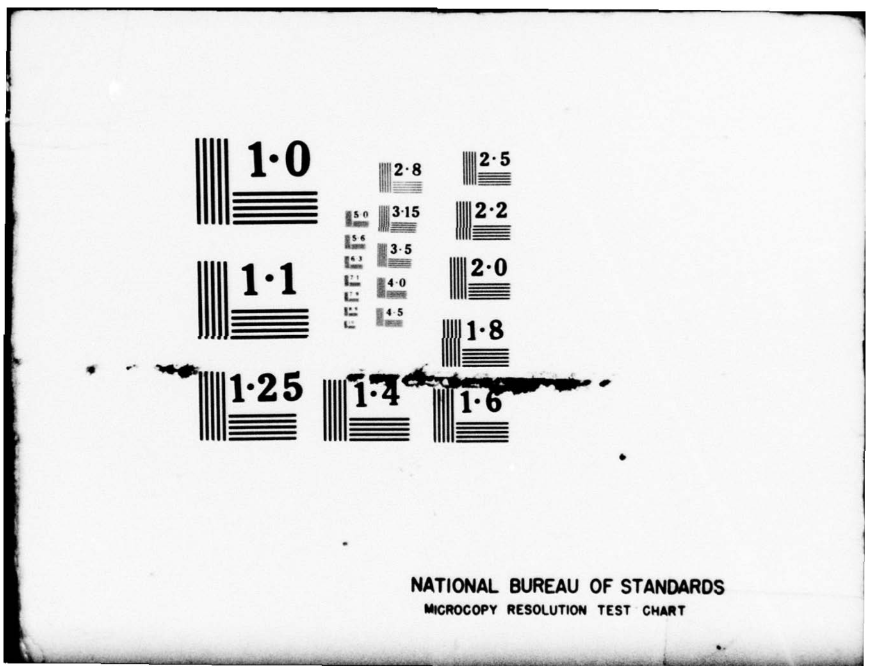
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DEPARTMENT OF TRANSPORTATION

COAST GUARD

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BULLETIN NO. 61

LEVEL

Report of the International Ice Patrol Service in the North Atlantic Ocean

SEASON OF 1975

CG-188-30

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16. Abstract

The 61st in a series of annual reports of the International Ice Patrol Service in the North Atlantic Ocean. Information of Ice Patrol organization, communications and operations, ice and environmental conditions and their relationship in 1975, and research conducted this year.

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16 REPORT OF THE INTERNATIONAL ICE PATROL SERVICE
IN THE NORTH ATLANTIC OCEAN

Season of 1975

CG-188-30

FOREWORD 14 USCG-BULL-61, USCG-188-30

Forwarded herewith is Bulletin No. 61 of the International Ice Patrol describing the Patrol's services, and ice observations and conditions during the 1975 season.

12 82 p.

N. C. VENZKE
Chief, Office of Operations

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PREFACE

This report is the 61st in a series of annual reports on the International Ice Patrol Service in the North Atlantic Ocean. It contains information on Ice Patrol organization, communications and operations, ice and environmental conditions and their relationship in 1975, and research conducted this year.

The authors of this report, Commander Albert D. SUPER, Lieutenant Harold G. KETCHEN and Marine Science Technician First Class Charles W. JENNINGS, all USCG, acknowledge ice and weather data provided by the Canadian Department of the Environment, sea surface temperature data provided by Commander, Maritime Command, Halifax, weather data provided by the U.S. National Weather Service, weather and oceanographic data provided by the U.S. Coast Guard Oceanographic Unit. Acknowledgement is also made to Yeoman Second Class Terry L. GEST, USCG, Chief Marine Science Technicians Walter P. ARK and Neil O. TIBAYAN, USCG, Marine Science Technician First Class Raymond J. EVERS, USCG, Marine Science Technician First Class Robert N. HILDEBRAND, USCG, and Marine Science Technician Third Class Paul A. LeBRUN, USCG, for their assistance in the preparation of the manuscript and illustrations for this report.

The continued assistance and cooperation provided by the Canadian Coastal Radio Station St. John's/VON in the relay of operational and administrative messages is gratefully acknowledged.

INTERNATIONAL ICE PATROL, 1975

The 1975 International Ice Patrol Service in the North Atlantic Ocean was conducted by the United States Coast Guard under the provisions of Title 46, United States Code, Sections 738, 738a through 738d, and the International Convention for the Safety of Life at Sea, 1960, Regulations 5 through 8. The International Ice Patrol is a service for observing and disseminating information on ice conditions in the Grand Banks Region of the Northwest Atlantic Ocean. During the ice season, the southeastern, southern and southwestern limits of the regions of icebergs in the vicinity of the Grand Banks of Newfoundland are guarded for the purpose of informing passing ships of the extent of this dangerous region. The International Ice Patrol also studies ice conditions in general with emphasis on the formation, drift and deterioration of icebergs, and assists ships and personnel requiring aid within the limits of operation of the Ice Patrol forces.

The International Ice Patrol is directed from the Ice Patrol Office located at the U.S. Coast Guard Base, Governors Island, New York. The Office gathers ice and environmental data from a variety of sources, maintains an ice plot, forecasts ice conditions, prepares the twice-daily Ice Bulletin, replies to requests for special ice information, and executes operational control of the Aerial Ice Reconnaissance Detachment, the Ice Patrol oceanographic cutter, and the Surface Patrol cutter when assigned.

Vice Admiral William F. REA, U.S. Coast Guard, was Commander, International Ice Patrol. Commander Albert D. SUPER, U.S. Coast Guard, was directly responsible for the management of the Patrol.

Preseason Ice Patrol northern reconnaissance missions were made in January and February, 1975 to assess the potential for season severity and locate the southern most icebergs. For the second consecutive year, Ice Patrol utilized St. John's, Newfoundland for its base of operations. The Aerial Ice Reconnaissance Detachment deployed to St. John's on March 17 and returned to the United States on June 23, 1975.

The 1975 Ice Season officially commenced at 0000 GMT, March 4, when the first Ice Bulletin was issued, and continued until the final bulletin was issued at 0000 GMT, June 24, 1975. The twice-daily Ice Bulletins were broadcast by the International Ice Patrol Communications Station Boston/NIK, U.S. Naval Radio Station Norfolk/NAM, Canadian Maritime Command Radio Station Mill Cove/CFH, and Canadian Coastal Radio Station at St. John's/VON. A facsimile ice chart was broadcast from Boston once each day. Iceberg information was also included on the regularly scheduled radio facsimile broadcasts of Naval Radio Norfolk/NFAX, CANMARCOM/CFH, Radio Bracknell/GFE, Radio Hamburg/DGC and Radio Quickborn/DGN.

The U.S. Coast Guard Cutter EVERGREEN, Commanded by Commander Martin J. MOYNIHAN, U.S. Coast Guard, conducted oceanographic and research cruises for the Ice Patrol from April 2 to 29 and May 20 to July 10, 1975. During these cruises EVERGREEN obtained oceanographic data along Ice Patrol standard sections to provide operational ocean current information, conducted iceberg drift studies, and deployed oceanographic current meters. The U.S. Coast Guard Cutter SHERMAN, Commanded by Captain James P. RANDLE, U.S. Coast Guard, deployed from June 7 to 25, 1975 and joined EVERGREEN for research studies of iceberg drift and deterioration. The Ice Reconnaissance Detachment participated in this phase by locating suitable icebergs for the studies and, on one occasion, dropped ice penetrometers into an iceberg to evaluate this method of affixing an instrument package or beacon to an iceberg. During this second cruise EVERGREEN also conducted two intensive oceanographic surveys to provide data for a Labrador Current model under development.

A surface patrol was not required this season.

During the 1975 Season an estimated 101 icebergs drifted south of 48°N.

AERIAL ICE RECONNAISSANCE

During the period September 1, 1974 to August 31, 1975 a total of 71 ice observation flights were flown. Preseason flights made in January and February accounted for 12 flights, and the remaining 59 flights were made during the ice season. There was no requirement for post-season flights. The objective of the preseason surveys was to study the iceberg distribution patterns in the Labrador Sea, to evaluate the iceberg potential of the developing ice season and to locate the southernmost icebergs. The season flight objectives were to locate the southwestern, southern, and southeastern limits of icebergs, to evaluate the short-term iceberg potential of the waters immediately north of the Grand Banks, and occasionally to study the iceberg distribution along the Labrador Coast. Several flights during the season were devoted to test and evaluation of a Side-Looking Airborne Radar (SLAR) in the development of an all-weather iceberg detection system. The flight statistics shown in Table 1 do not include the flight time required to make the passages between U.S. Coast Guard Air Station, Elizabeth City, North Carolina and the operating base for crew relief or aircraft maintenance.

Aerial ice reconnaissance was accomplished by U.S. Coast Guard HC-130-B (Lockheed Hercules) four-engine aircraft from the Coast Guard Air Station at Elizabeth City, North Carolina.

Table 1—Aerial Ice Reconnaissance Statistics September 1974 through August 1975

Month	*Number of Flights*	*Flight Hours*
PRESEASON		
September-December	0	0
January	4	22.5
February	3	14.2
March	5	36.2
Preseason total	12	72.9
SEASON		
March	7	51.1
April	14	89.3
May	27	161.0
June	11	59.0
July	0	0
August	0	0
Season total	59	360.4
Annual total	71	433.3

During the iceberg season, the aircraft operated out of Torbay Airport, St. John's, Newfoundland.

On March 17 the Ice Reconnaissance Detachment deployed to St. John's from Elizabeth City. The main base of operation for the Detachment remained at St. John's until June 23 when they returned to Elizabeth City. Aircraft, crew and ice observers were exchanged at approximately three week intervals.

COMMUNICATIONS

Ice Patrol communications included ice reports, environmental conditions, Ice Bulletins, special ice advisories, a daily facsimile chart, and the administrative and operational traffic necessary to the conduct of the Patrol. The Ice Bulletin was transmitted by teletype from the Third Coast Guard District Communications Center in New York twice each day to over 30 addresses, including those radio stations which broadcast the Bulletin. These stations were the U.S. Coast Guard Communications Station Boston/NIK/NMF, U.S. Naval Radio Station Norfolk/NAM, Canadian Coastal Radio Station, St. John's/VON and Canadian Forces Maritime Command Radio Station, Mill Cove/CFH.

Coast Guard Communications Station Boston transmitted the Bulletin by CW at 0018 GMT on 5230 and 8502 kHz and at 1218 GMT on 8502 and 12750 kHz. After a 2-minute series of test signals the transmissions were made at 25 words per minute and then repeated at 15 words per minute. Coast Guard Communications Station Boston/NIK also transmitted a daily radio facsimile broadcast depicting the locations of icebergs and sea ice at 1600 GMT simultaneously on 8502 and 12750 kHz at a drum speed of 120 revolutions per minute.

Ice Bulletins were also broadcast via CW twice daily by U.S. Naval Radio Station Norfolk/NAM at 0430 and 1700 GMT on 88.0 (except the Tuesday 1700 GMT transmission was made on 134.9 kHz), 8090, 12135, 16180, 20225 (1700 GMT only) and 25590 (1700 GMT only) kHz; Canadian Maritime Command Radio Station Mill Cove/CHF at 0130 and 1330 GMT on 438 (except the 1330 GMT transmission the second Thursday each month), 4356.5, 6449.5, 8662, 12984, 17218.4 and 22587 (on request) kHz; and Canadian Coastal Radio Station St. John's/VON at 0000 and 1330 GMT on 478 kHz. Radio facsimile broadcasts that included the limits of icebergs were made by Fleet Weather Central Norfolk/NFAX at 1805 GMT on 4957, 8080, 10865, 16410 and 20015 kHz; Canadian Maritime Command Radio Station Mill Cove/CHF at 0000 and 1200 GMT on 133.15, 4271, 9890, 13510 and 17560 kHz; Radio Station Bracknell/GFE at 1400 GMT on 4782, 9203, 14436 and 18261 kHz; and Radio Station Hamburg/DGC and Radio Station Pinneburg/DGN at 0905 and 2145 GMT on 3695.3 and 13627.1 kHz. All radiofacsimile broadcasts were made at a drum speed of 120 revolutions per minute.

Special broadcasts were made by Canadian Coastal Radio Station St. John's/VON as required when icebergs were sighted outside the limits of ice between regularly scheduled broadcasts. These transmissions were preceded by the International Safety Signal (TTT) on 500 kHz.

Merchant ships calling to transmit ice sightings, weather and sea surface temperatures were requested to use the regularly assigned international call signs of the Coast Guard Ocean Weather Station HOTEL, East Coast AMVER Radio Stations, or Canadian Coastal Radio Station St. John's/VON. All Coast Guard Stations were alert to answer NIK/NIDK calls, if used.

Ice information services for the Gulf of St. Lawrence, as well as the approaches and coastal waters of Newfoundland and Labrador, were provided by the Canadian Department of the Environment from December until approximately

Table 2—Communications Statistics

Number of ice reports received from ships	192
Number of ships furnishing ice reports	101
Number of ice reports received from commercial aircraft	5
Number of sea surface temperature reports	1050
Number of ships furnishing sea surface temperature reports	57
Number of ships requesting special ice reports	10
Number of NIK Ice Bulletins issued	224
Number of NIK facsimile broadcasts	111

late June. Ships obtained ice information by contacting the Ice Operations Officer, Sydney, Nova Scotia via Sydney Marine Radio/VCO or Halifax Marine Radio/VCS.

Communications statistics for the period 1 September 1974 through 31 August 1975 are shown in Table 2.

Of the fifty-seven ships furnishing Ice Patrol with sea surface temperature information the eleven most outstanding contributors were:

USCGC SHERMAN/NMMJ
M/V ATLANTIC SPAN/SLPN
M/V HURON/CGXY
M/V LONDON TRADITION/MXYC
M/V STADT BREMEN/DECP
M/V MINERAL SERAING/ONMO
M/V STADT WOLFSBURG/DCWE
M/V LONDON PRIDE/GOSH
USNS NEPTUNE/NGUB
M/V AMSTEL HOF/PCPL
M/V NORSE FALCON/GUMW

Table 3—Estimated Number of Icebergs South of Latitude 48 N, Season 1975

	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTAL
1975	1	0	0	0	0	24	41	10	20	5	0	0	101
TOTAL 1946–1975	10	2	4	11	64	261	1035	2926	2830	1716	480	100	9,439
AVERAGE 1946–1975	0	0	0	0	2	9	35	98	94	57	16	3	315
TOTAL 1900–1975	256	109	110	91	184	712	3137	7771	9913	5234	1676	489	29,682
AVERAGE 1900–1975	3	1	1	1	2	9	41	102	130	69	22	6	391

ICE CONDITIONS, 1975 SEASON

September-December 1974

After the close of the 1974 Season, the second heaviest on record, a few icebergs reached the waters immediately north of the Grand Banks. The southernmost of these was reported on 11 September as a large berg in position 47°59′N, 45°48′W. On 8 October, a merchant ship sighted an iceberg "140 miles after leaving Cape Race". Ice Patrol was unable to contact the reporting ship to confirm this report and no other reports of this iceberg were received. Otherwise, there was no ice reported south of 51°N from September through December. By the first of September all sea ice had melted in Baffin Bay. New ice did not start forming again until late September along the east coast of Ellesmere Island and in isolated bays and coves along the Baffin Island coast. Freeze-up began in earnest in Baffin Bay in mid-October, with a very rapid ice growth during late October through the first half of November. Slightly above average growth rates continued for the remainder of the year. On 20 November, a U.S. Navy ice reconnaissance flight with an Ice Patrol observer on board covered the waters along the coast of Labrador and southern Baffin Island. Only three icebergs were sighted, all north of Cape Chidley. The following day, an aerial survey was completed in central Baffin Bay south of 76°N. When compared to a similar survey in October, 1970, there were relatively few bergs observed south of 73°N. On 22 November, the east coast of Greenland was surveyed between 65°30′N and 76°N. A surprising number of large icebergs were sighted. Under ideal conditions, some of these bergs would survive a drift from East Greenland across the Labrador Sea or Davis Strait and then south to the Grand Banks. By the end of December, sea ice cover extended from the coast of Greenland near Sondrestrom Fjord in a southeasterly direction to about 100 nautical miles east of Hudson Strait, then southerly along the Labrador coast to 52°30′N (just north of the Strait of Belle Isle). Very open pack new ice developed over the eastern half of the Strait and new ice was beginning to form in some sheltered shallows of Notre Dame Bay and Newfoundland's Northern Peninsula.

January 1975

Only one iceberg (53°05′N, 52°05′W) was reported by maritime traffic in January. Although retarded somewhat during the first week of January, the overall trend was for normal ice growth east and northeast of Newfoundland. By the middle of the month, the Strait of Belle Isle was covered and ice was spreading into Newfoundland waters. Notre Dame Bay remained ice free until near the end of the month when new and grey ice were first observed. By the end of January, new ice had formed in Bonavista Bay and the heavier Labrador pack was moving south of 51°N. A preseason survey was conducted January 20–28 along the coasts of Labrador and Baffin Island as far north as Cape Christian and across Davis Strait to the west Greenland coast (See Figure 1). Iceberg populations south of Davis Strait were estimated to be about one half the 1963–1974 average. There were no icebergs sighted during the flights south of Hamilton Inlet and only four icebergs between 54°N and 55°N. The southernmost of these were two small bergs located at 54°23′N 54°18′W and 54°25′N, 54°37′W. The latitudinal iceberg distribution is illustrated graphically in figure 2. No large icebergs were sighted south of Cape Chidley and the bergs located north of there were small and very weathered. Considering the lack of sizable icebergs, the small total population and the northern position of the main iceberg grouping, it was predicted that the 1975 iceberg season would see a below normal number of icebergs reaching the Grand Banks and the season would begin later than usual.

February 1975

During the first half of February, three iceberg reports were received. The southernmost, 50°18′N 51°08′W, was reported as a large berg on 8 February. Early February saw a very rapid south-southeastward spread of pack ice. Ice conditions on the Grand Banks equalled those of the same period last year, the most severe sea ice year in decades. A mean offshore ice drift during the period prevented any serious ice congestion along Newfoundland's east coast. Ice growth continued during the last half of the month, although at a decreased rate. Ice drifting south added to the pack off Newfoundland. Although the ice cover was above normal, thicknesses were much less than in 1974. By the end of February, sea ice had reached a southeastern limit roughly defined by a line from 45°15′N, 48°20′W to 46°10′N, 46°35′W. Iceberg sightings became more numerous as favorable environmental conditions speeded the few icebergs south toward the Grand Banks. Late February preseason flights, 24 February to 12 March (See Figure 3), revealed only 66% of the normal iceberg population south of Davis Strait along the Baffin Island and Labrador coasts. As in the January surveys, there was a predominance of small icebergs in these upstream regions. The latitudinal iceberg distribution is illustrated graphically in figure 4. A strong southerly flow and an apparent greater than normal mass transport along the Labrador coast from mid-January through February brought the icebergs from coastal Labrador onto the Grand Banks considerably earlier than expected. The southernmost, a small berg was sighted in position 43°58′N, 47°40′W on 1 March. The easternmost iceberg of the month was reported on 25 February as a small iceberg (47°08′N, 47°20′W). Although numbers were low and sizes small, an estimated 24 icebergs had already crossed 48°N during February. This is well above the 75 year average of 9 iceberg crossings in February.

March 1975

With the unexpected acceleration in the southward drift of icebergs during February, a number of icebergs began to exit the southeast cover of sea ice posing a threat to trans-Atlantic traffic. Considering this, the 1975 Ice Patrol service was officially started on 4 March. Figure 5 shows the iceberg locations as observed during aerial reconnaissance flights on 1 and 7 March. These two flights established the limits of all known ice for the start of the season. The first regular season deployment of the Ice Reconnaissance Detachment occurred on 17 March with aircrew and ice observers moving to St. John's, Newfoundland. On 18 and 19 March, consecutive ice reconnaissance flights (Figure 6) revealed 30 icebergs and 10 growlers below 48°N, but most of these were relatively small in size and showed signs of advanced stages of deterioration. Although sea ice cover was more extensive than normal during the first half of March, the ice east of Newfoundland continued to be thin and of very loose composition. Predominant mild wind flow from the southwest caused early deterioration and recession of the sea ice limits beginning in mid-month. On 26 March, no heavy concentrations of sea ice existed below 48°N although some brash and small cakes of diffused ice extended to 45°N. By the end of March, the concentrated pack had retreated to approximately 49°N with only very diffuse ice extending to 45°N (figure 8). The southernmost iceberg for the month was observed on 27 March (42°50′N, 49°20′W). This was followed three days later by the sighting of a growler, believed to be the same piece of ice, in position 42°38′N, 49°30′W. A total of 41 icebergs crossed 48°N during March. This peak in the iceberg population on the Grand Banks occurred a full month earlier than usual and accounted for over 40% of the total number of icebergs that would cross 48°N during 1975. One unusual berg sighting was reported outside the Ice Patrol area by the Icelandic cargo vessel SKAFTAFEIL on 28 March. This iceberg was encountered some 400 miles southeast of Cape Farewell, Greenland in position 55°15′N, 35°04′W.

April 1975

The sea ice edge off Newfoundland/Labrador continued to move northward during April, resulting in increased iceberg melt rates for the already rapidly decaying population. The southernmost berg (42°36′N, 50°03′W) during the month was last seen on 1 April. The southernmost piece of ice for the 1975 season, a growler, was sighted on 4 April in position 41°44′N, 48°45′W. A series of flights on 1, 2 and 3 April, averaging better than 80% visual coverage along

the track shown in figure 9, located only 22 icebergs and 12 growlers strung out from 51°N to the Tail of the Banks and east to Flemish Cap. Fifteen (15) of these were already south of 48°N, having crossed during March. They had decayed significantly since previously sighted. Although a few were scattered to the south and east, the major grouping was clustered around 46°30'N, 47°W. By the end of the first week in April, all sea ice was north of 49°N with the concentrated pack north of 50°N and west of 51°W. The southern ice limit consisted of open pack, thin first year. The number of icebergs on the Grand Banks gradually dropped during the month due to the increased melt rate and small supply of upstream icebergs flowing into the area. Flights on 15, 16 and 19 April (See Figure 11) found only 15 icebergs below 48°N, the southernmost being at 44°30'N, and only 11 growlers and one small iceberg between 49°N and 50°N. By 28 April, there were only 28 icebergs and growlers south of 52°N being tracked by the Ice Patrol (See Figure 12). Since the Ice Patrol tends to be conservative in removing icebergs from this plot, some of these icebergs may have been duplicates with slightly different positions from two or more sources, or they may have already completely melted. Only 10 bergs were estimated to have crossed 48°N during the entire month of April, usually the most active iceberg month of the year on the Grand Banks. This number represents only 10% of the long-term normal for April.

May 1975

On the 3rd and 4th of May, flight tracks (figure 13) were flown with reasonably good visibility encountered. A total of 12 icebergs and 15 growlers were sighted south of 48°N, all of these located just to the north or west of the Grand Banks. Repeat sightings have been removed from figure 13. A group of 4 icebergs and 5 growlers, grouped within a 30 mile radius of 42°30'N, 48°30'W, marked the southern limit of all known ice at the time. The western berg of this group (sighted on 5 May), was reported two days later by the British passenger liner ORIANA in position 41°45'N, 47°58'W. This proved to be the southernmost iceberg reported during 1975. On 5 May there was no sea ice south of 51°N or east of 53°W (figure 4). No icebergs were sighted east of 44°W off the Grand Banks in 1975, although a number of bergs were reported in the vicinity of Flemish Cap between 44°W and 46°W, the easternmost of these, a medium iceberg (47°05'N, 44°42'W) and four growlers (out to 47°01'N 44°30'W), were observed on 14 May. Beside these sightings, flights on 13, 14, and 15 May located only two small icebergs (one with a number of growlers) south of 47°30'N (figure 15). Also sighted were a large berg (47°57'N, 49°08'W) and 3 medium and 3 small bergs with growlers off Cape St. Francis, all of which were resighted further south on 20, 22, and 23 May (figure 16). On 19 May, a coastal flight was made along Newfoundland and Labrador coasts up to 56°N. Although visibility was generally poor for most of the flight, 3 medium and 10 small icebergs were sighted south of 52°N in Bonavista and Notre Dame Bays and off Cape Freels. Most of these were grounded and were not considered to present a serious threat to the Grand Banks area unless a sustained period of offshore winds occurred in late May or early June. A total of 20 icebergs were estimated to have crossed 48°N during this month, which is considerably less than the normal of 94. Most of these crossed 48°N while in the Avalon Channel between 52°W and the Newfoundland coast.

June 1975

In early June the only sea ice south of 52°N was very diffuse and rotted ice along the northeast coast of Newfoundland (figure 17). The only ice south of 48°N and east of 51°W that had not yet melted were the remains of a large iceberg first sighted on 14 May and possibly the last of a small iceberg last sighted by Ice Patrol on 23 May. These small bergs and growlers were deteriorating rapidly in an area southeast of the Banks (figure 17). As is typical in the spring, fog and low cloud cover reduced visibility on the Grand Banks to near zero for most of June. Reconnaissance flights on 11 and 12 June averaged less than 30% visual coverage along the tracks flown (figure 18). With the exception of sighting those icebergs scattered along the coast and south of Newfoundland (all west of

51°30′W), no iceberg reports were received in June after the 4th. All ice south of 48°N was calculated to have melted in mid-June, but without visual confirmation that all of the icebergs previously spotted south of Newfoundland had totally disintegrated, the Ice Patrol service continued. Finally a break in the weather occurred on 20 and 21 June. Two flights provided confirmation that no ice existed south of 47°30′N. One small iceberg with growlers had drifted south and grounded off St. John's during the third week of June but it presented no threat to the Grand Banks. With this information and knowledge that the upstream iceberg population was sparse and had little potential of producing a berg that would reach 47°N, notice was given to the maritime community that International Ice Patrol services would be terminated on 23 June. The Ice Patrol Reconnaissance Detachment returned to the United States on that date. It was estimated that a total of 5 icebergs crossed 48°N during June.

July-August

No more icebergs were known to have drifted south of 48°N during July or August. The total count of icebergs crossing 48°N for 1975 was 101. Although a number of sightings continued to be reported to the Ice Patrol during the summer, most were located just east of the Strait of Belle Isle. One exception was a group of bergs sighted between 48°34′N–48°49′N and 48°33′W–49°05′W. These were resighted again slightly further south on 8 August. In July only belts and strips of sea ice existed off the Labrador coast and the only concentrated pack was off Baffin Island between 62°N and 72°N. By mid-August, this entire area was free of sea ice.

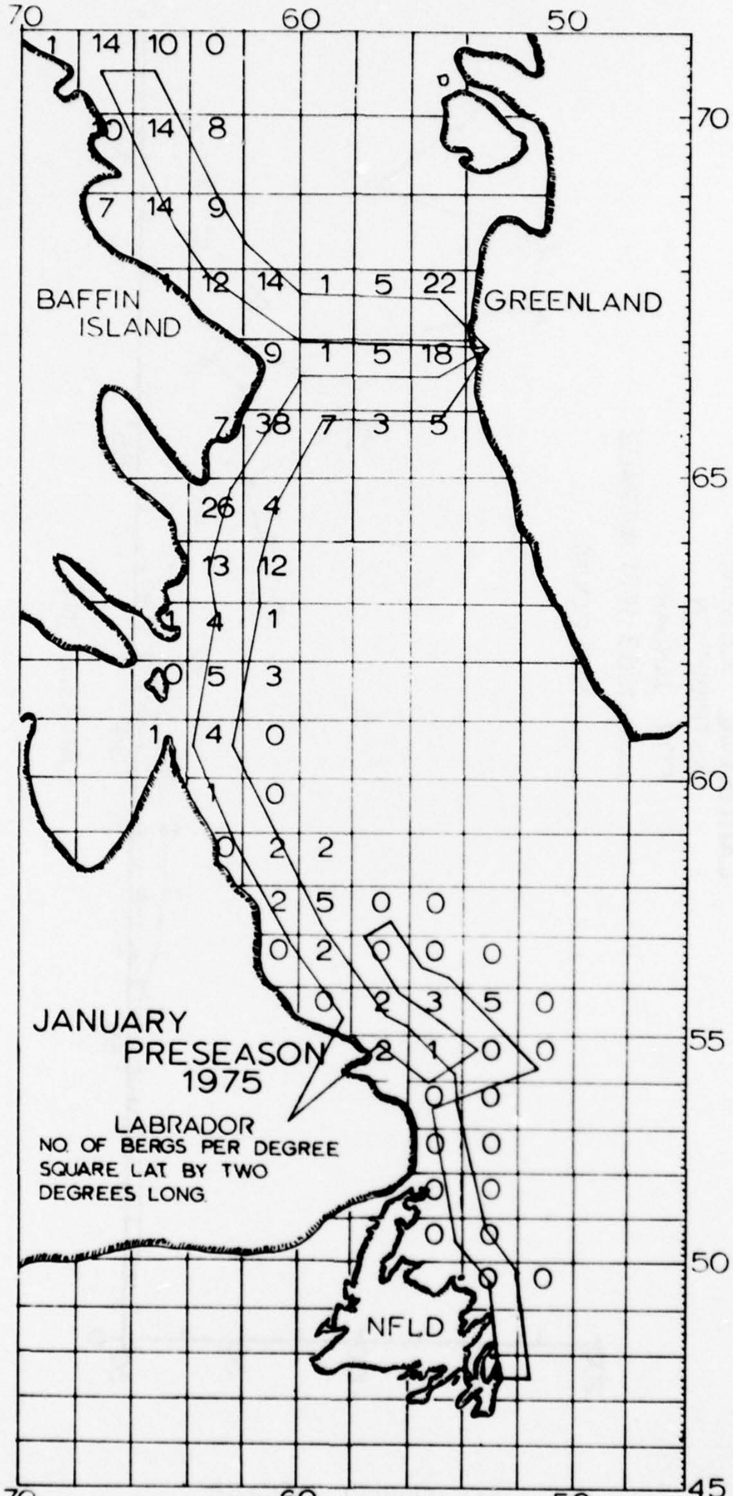

Figure 1.—Preseason Iceberg Survey 20–28 January 1975

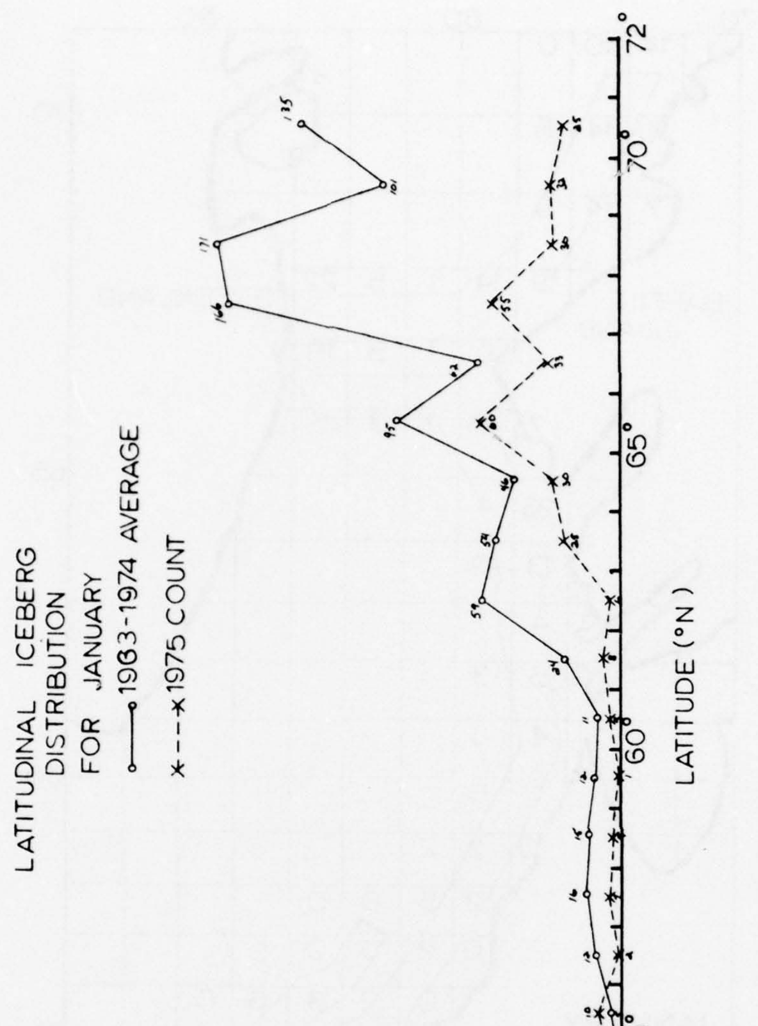

Figure 2.—Latitudinal Iceberg Distribution, JANUARY PRESEASON FLIGHTS

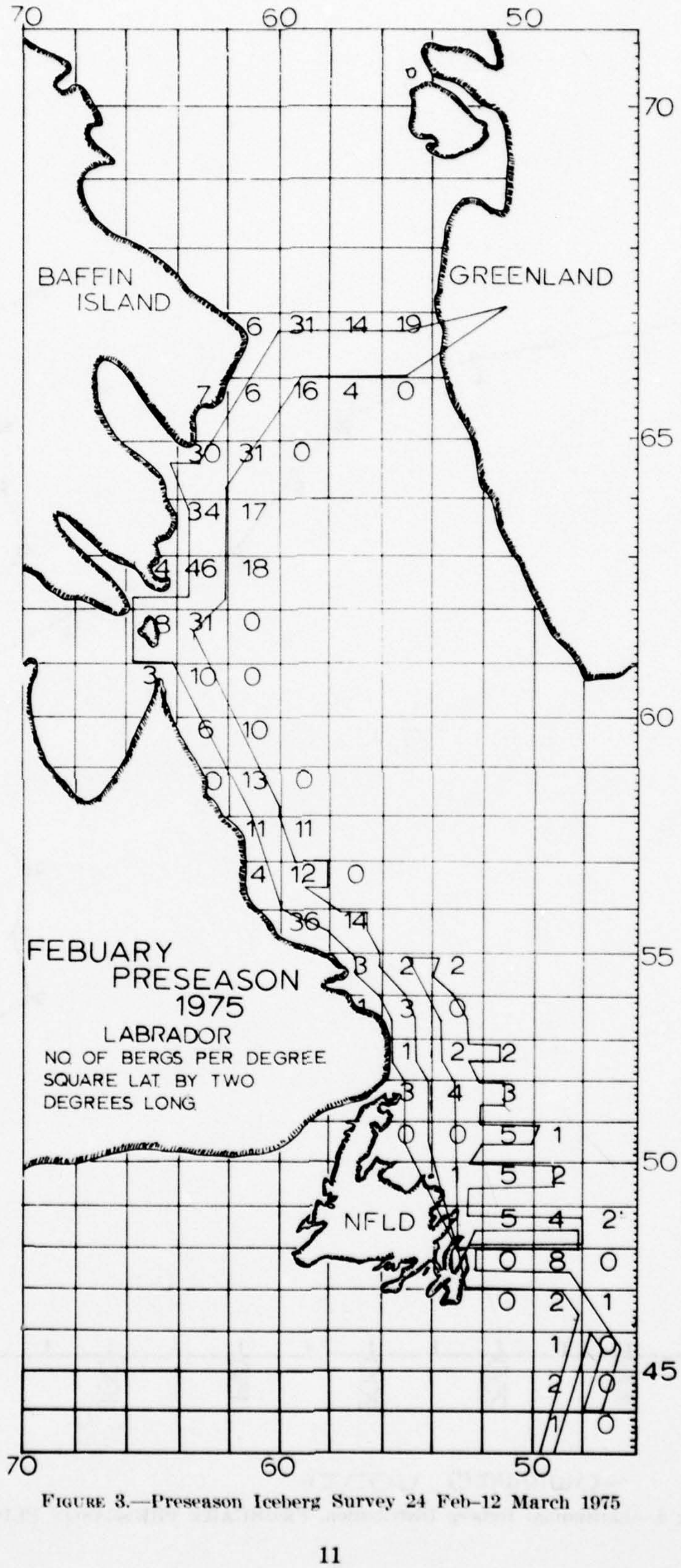

FIGURE 3.—Preseason Iceberg Survey 24 Feb–12 March 1975

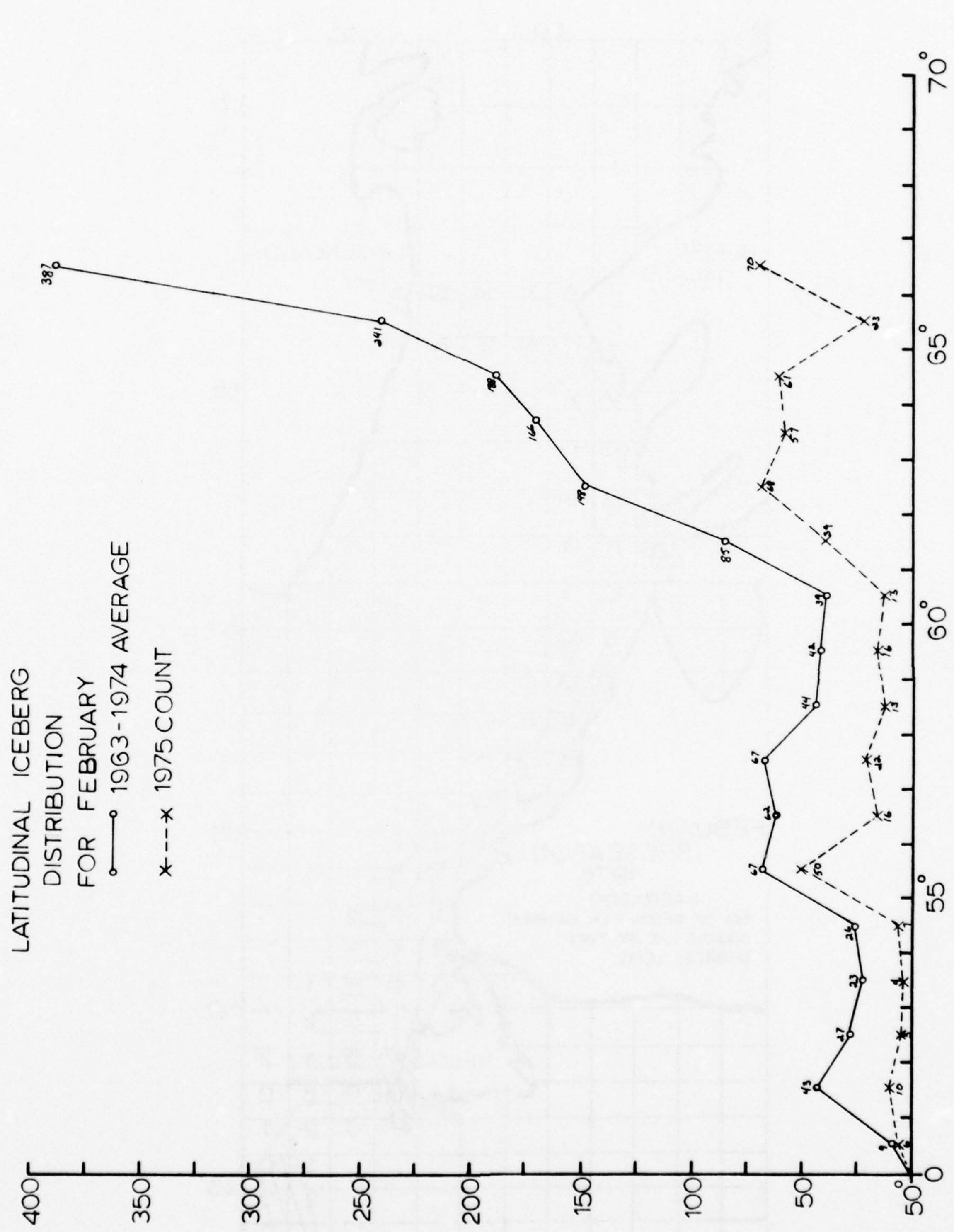

Figure 4.—Latitudinal Iceberg Distribution, FEBRUARY PRESEASON FLIGHTS

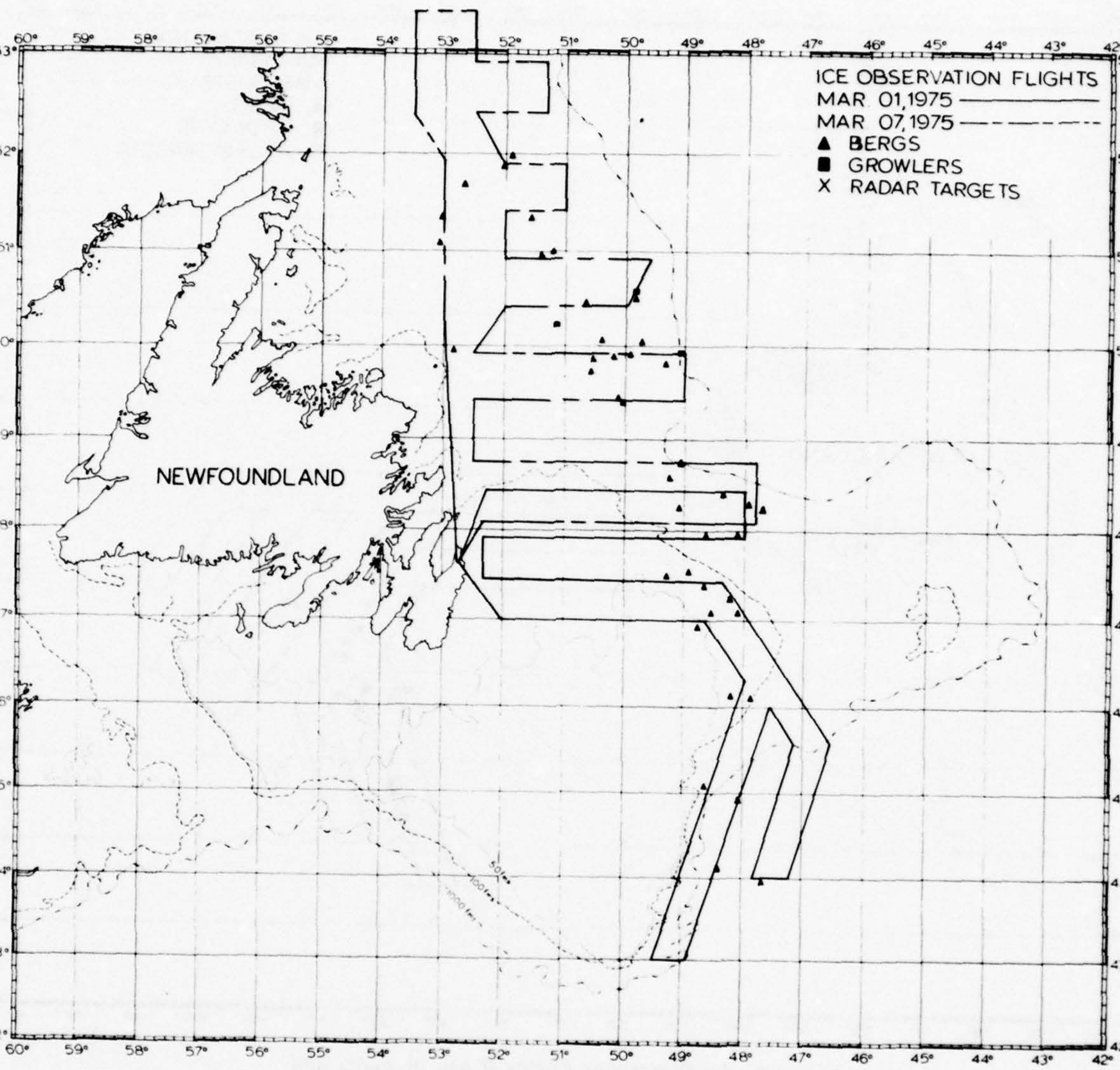

FIGURE 5.—Ice Observation Flights 1 and 7 March 1975

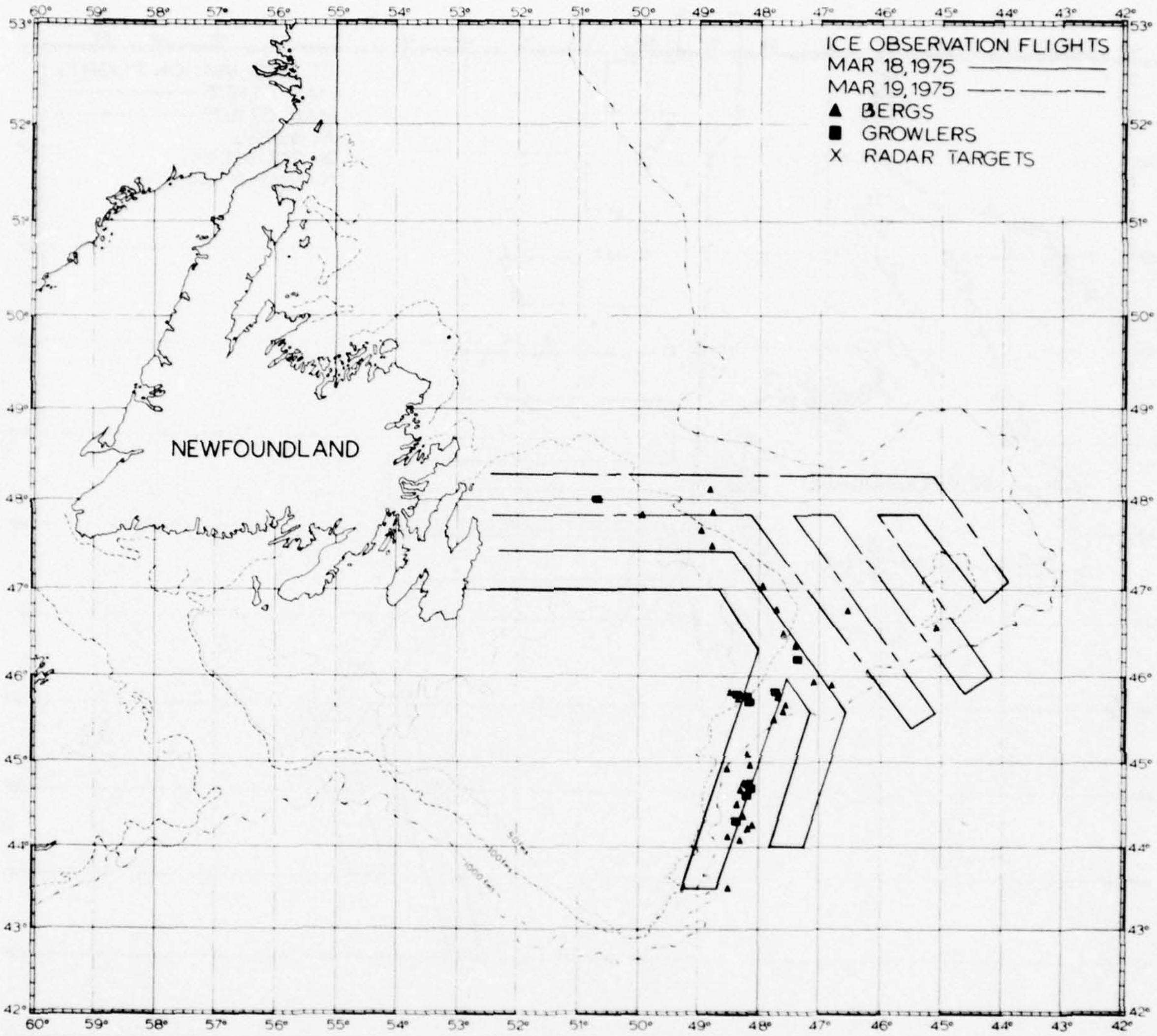

Figure 6.—Ice Observation Flights 18 and 19 March 1975

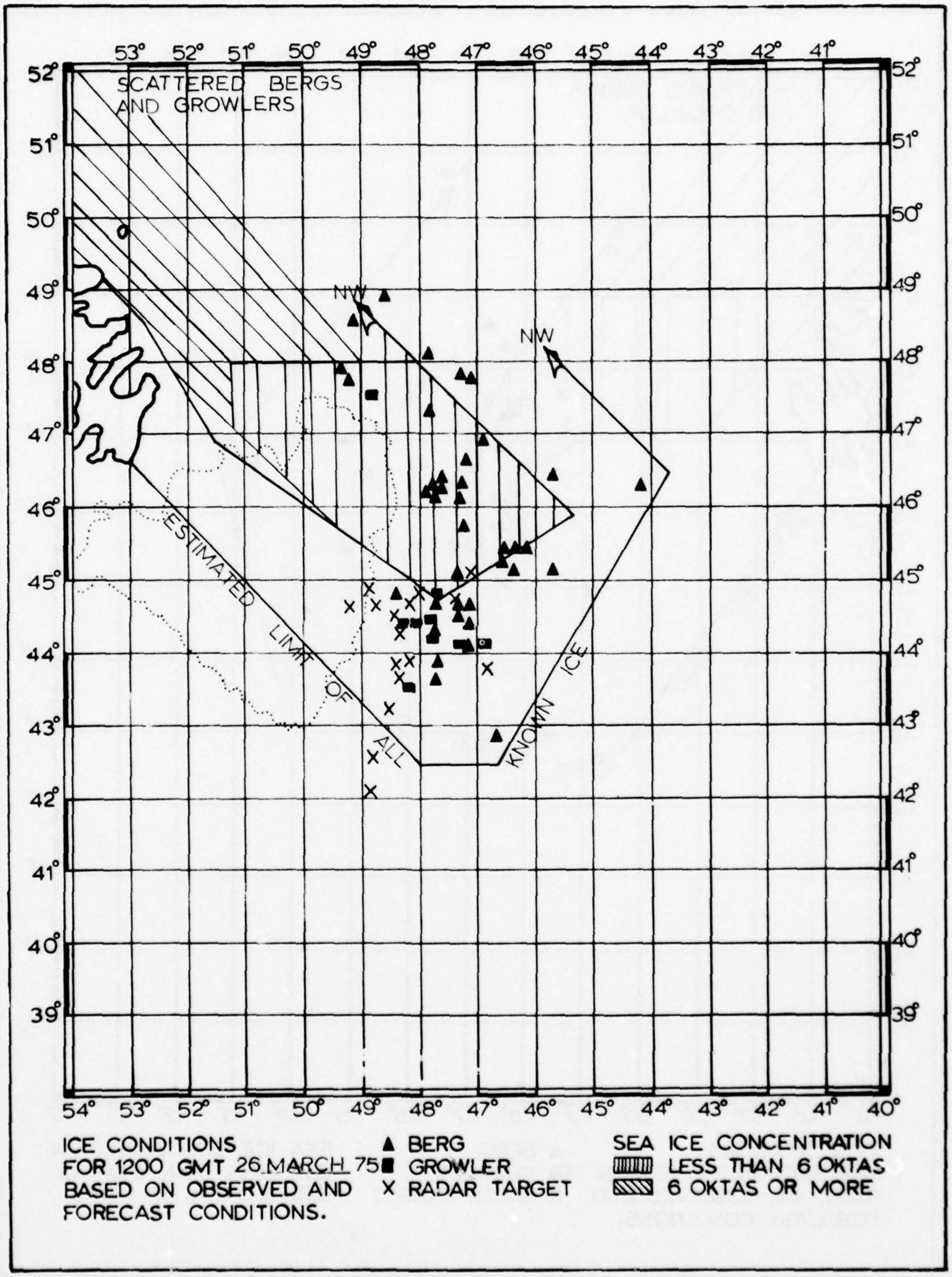

FIGURE 7.—Ice Conditions, 1200 GMT 26 March 1975

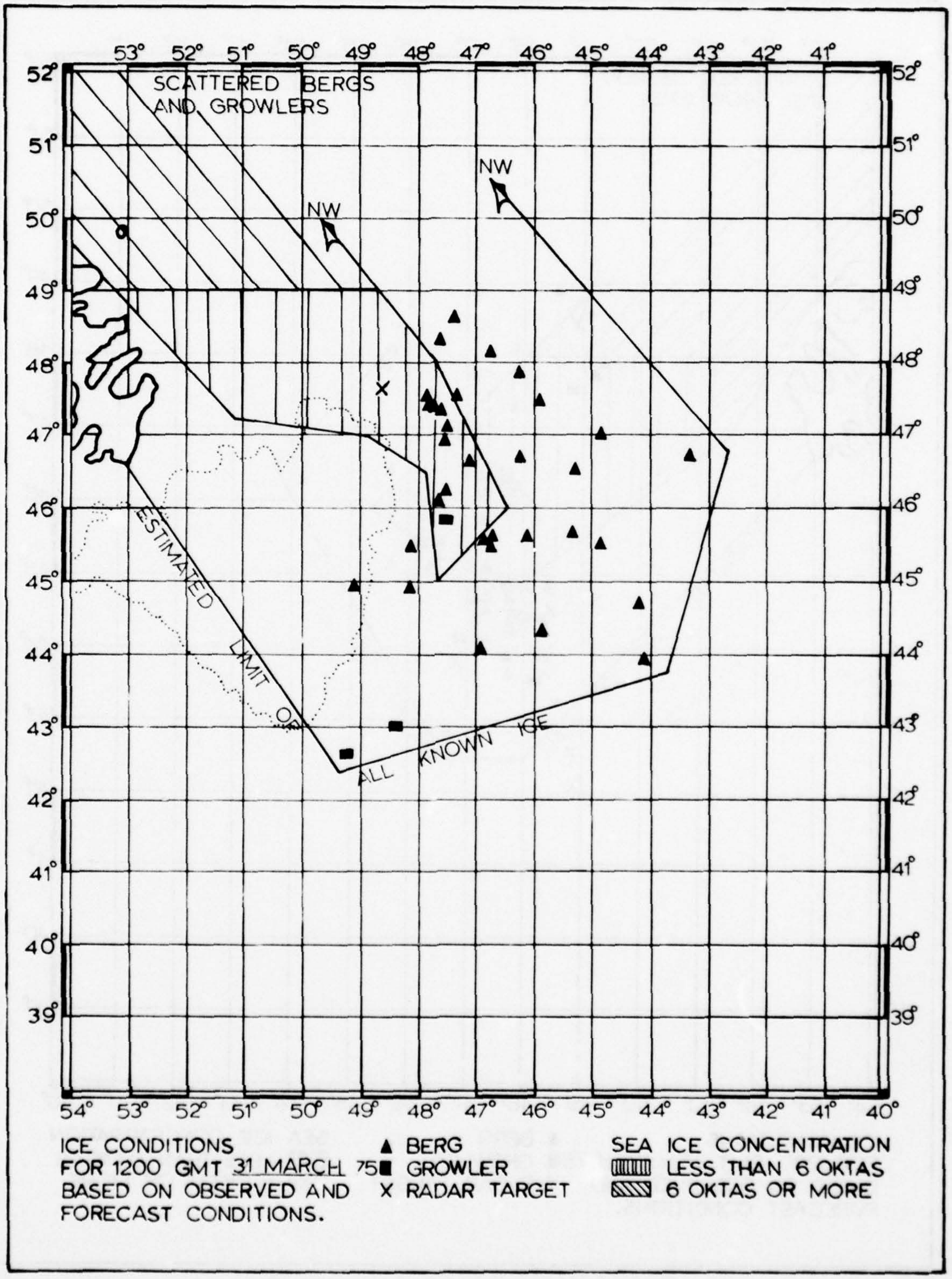

FIGURE 8.—Ice Conditions, 1200 GMT 31 March 1975

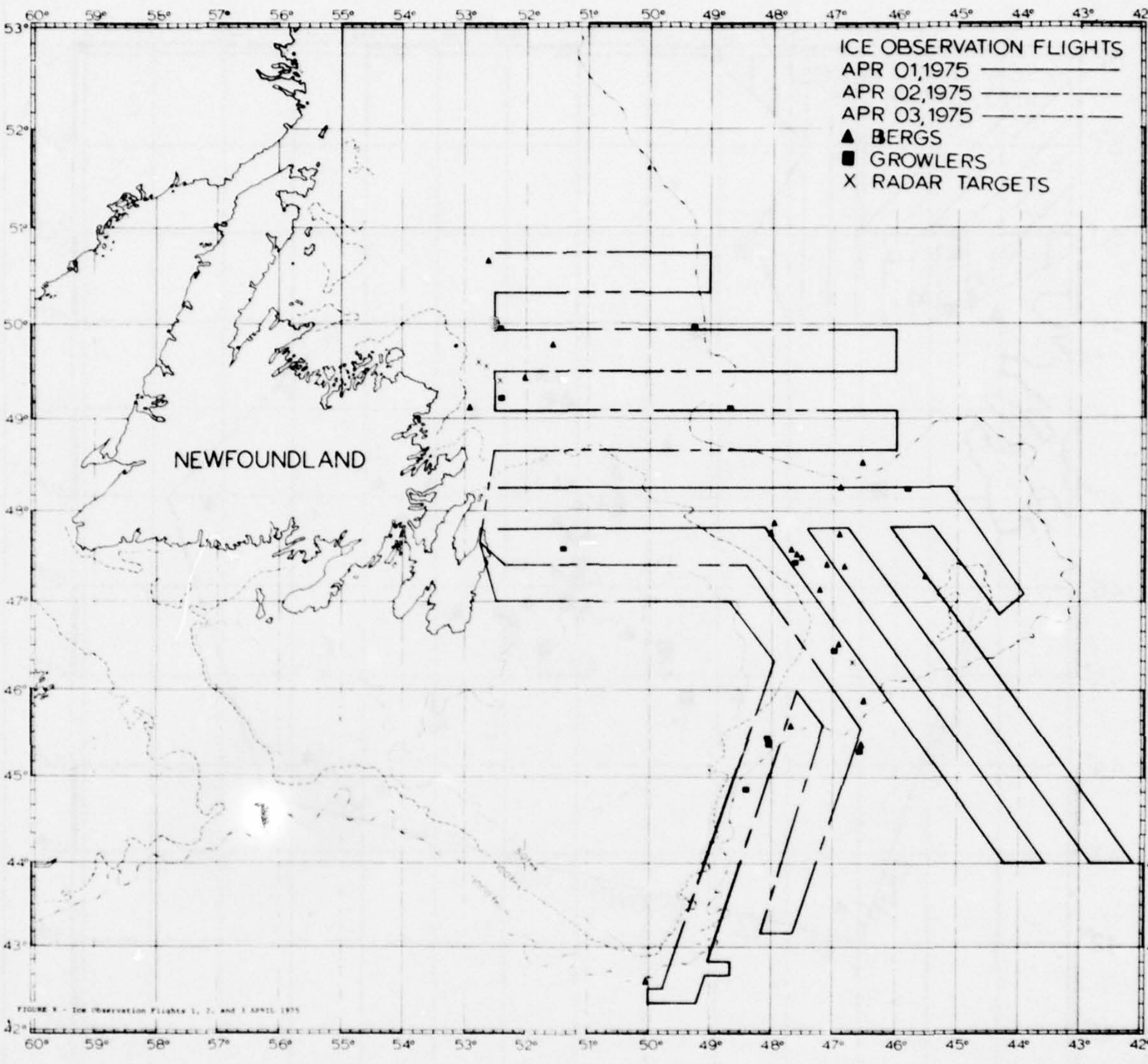

FIGURE 9.—Ice Observation Flights 1, 2, and 3 April 1975

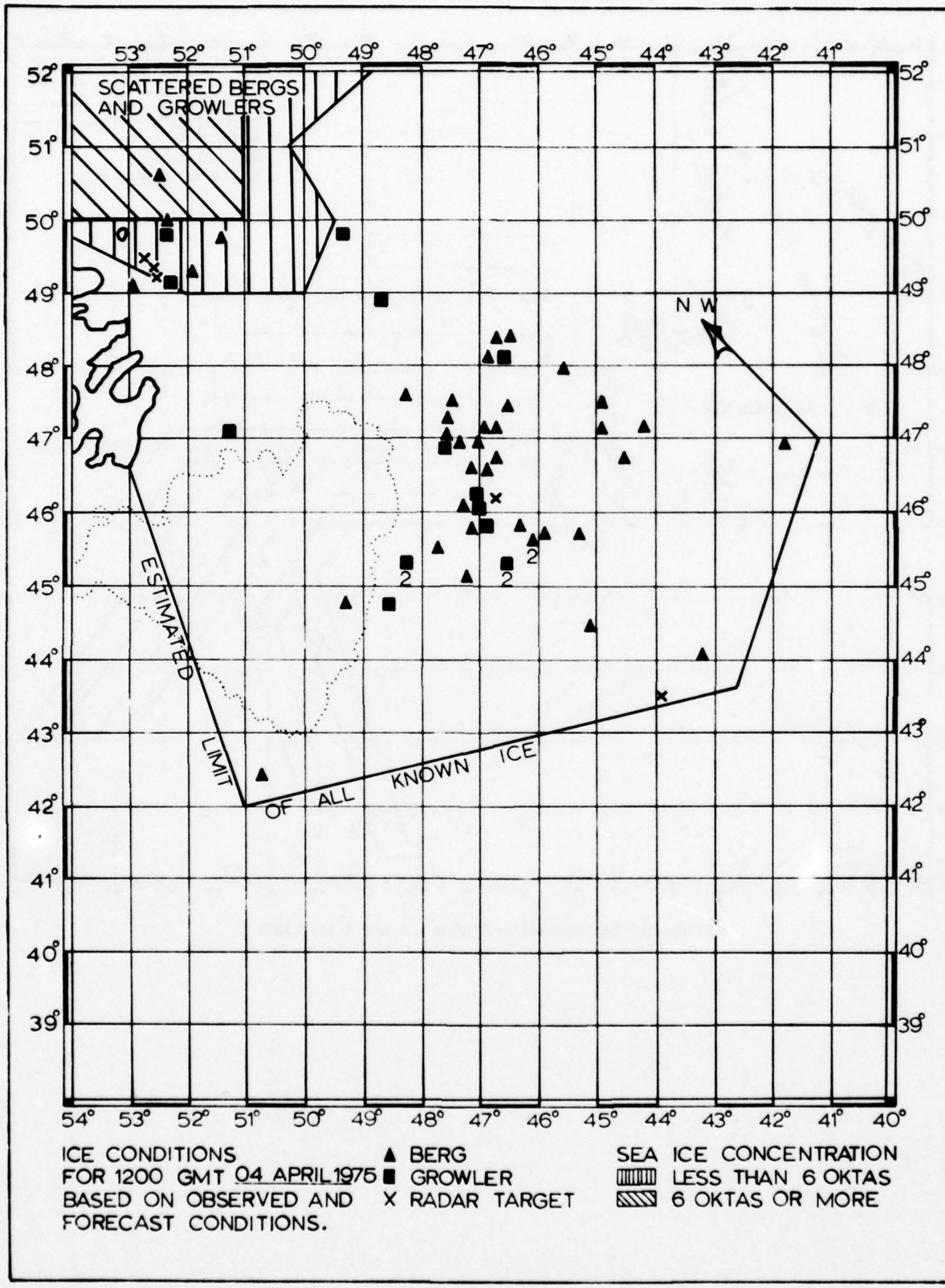

FIGURE 10.—Ice Conditions, 1200 GMT 4 April 1975

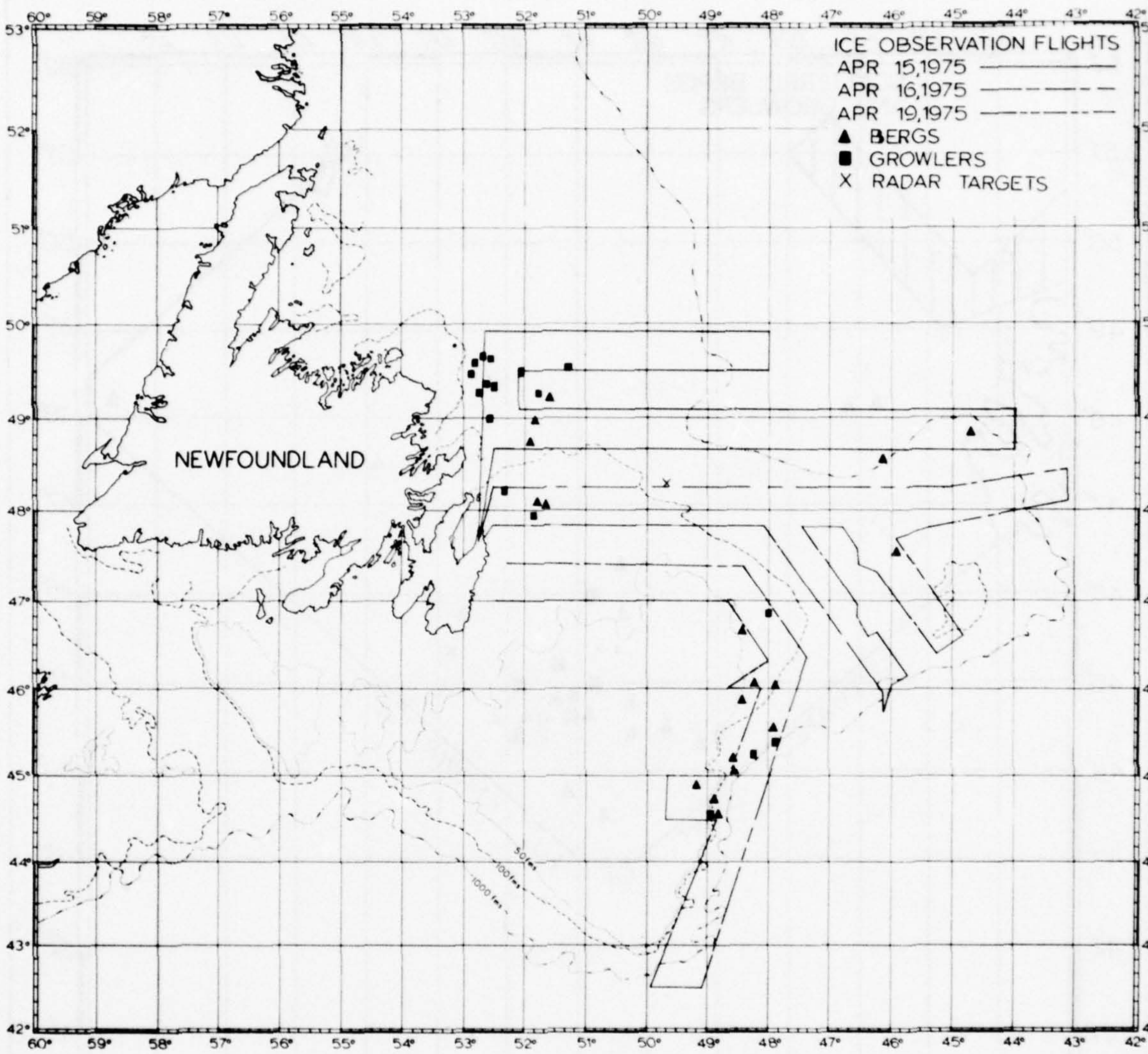

FIGURE 11.—Ice Observation Flights 15, 16, and 19 April 1975

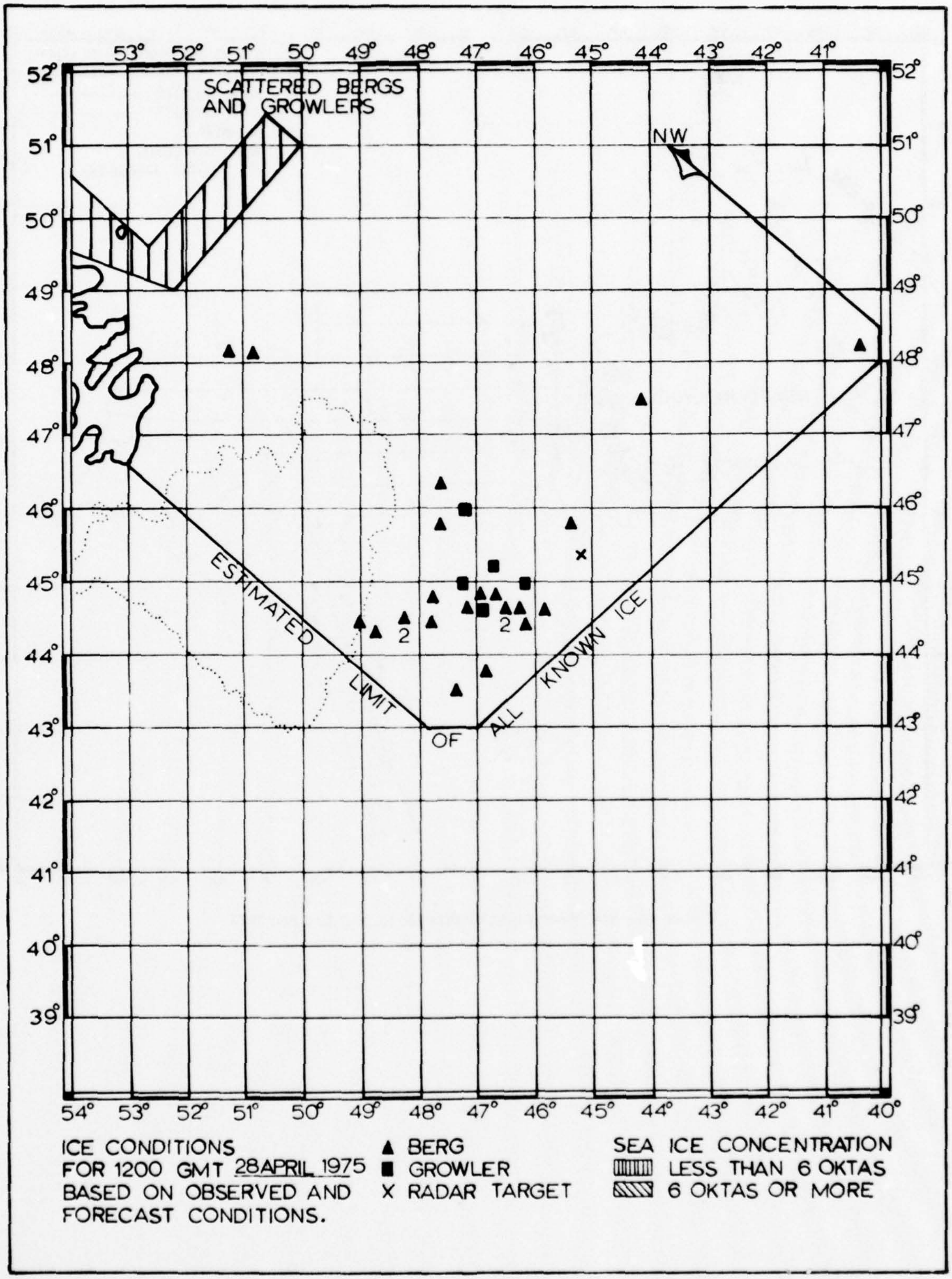

FIGURE 12.—Ice Conditions, 1200 GMT 28 April 1975

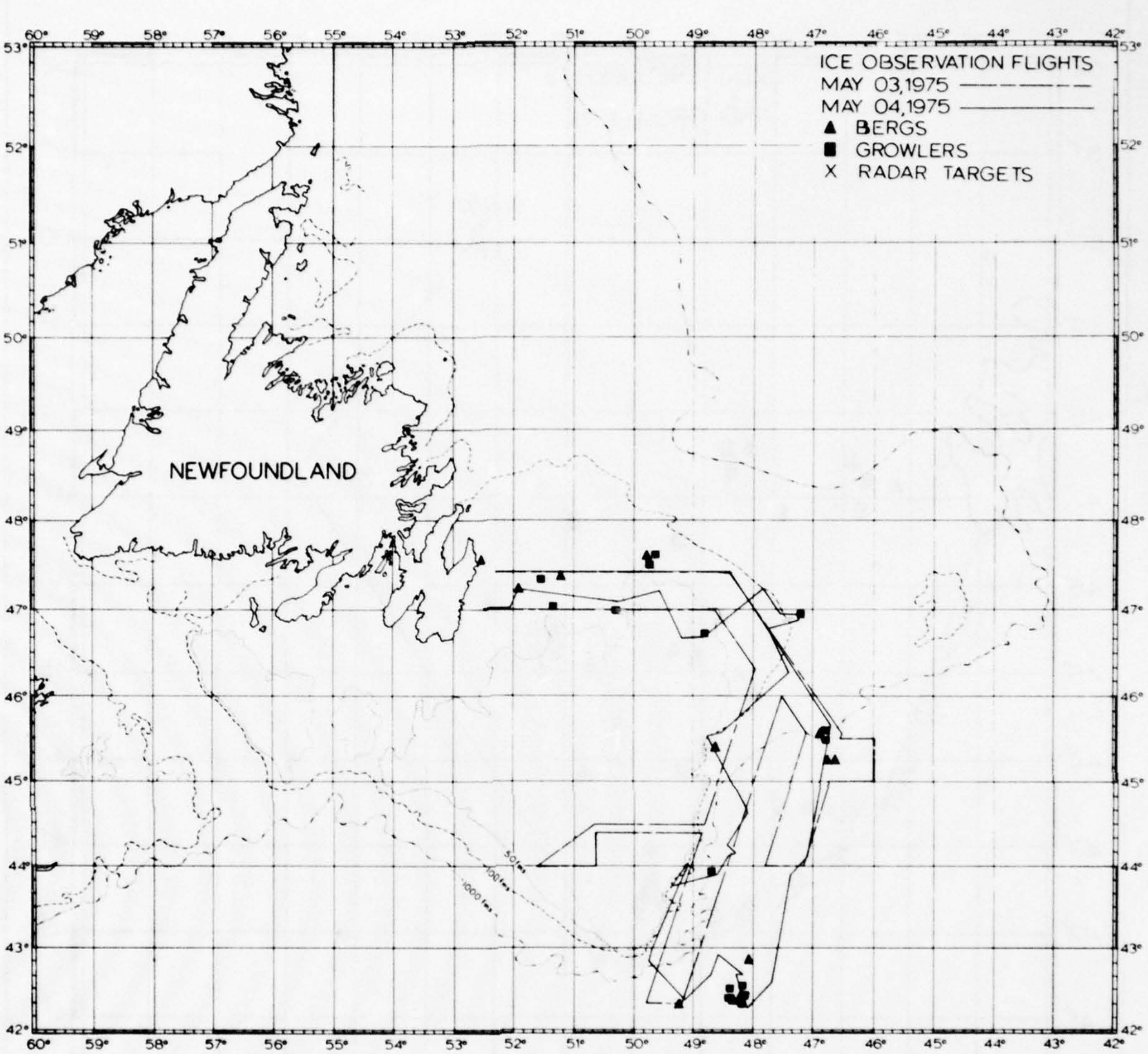

FIGURE 13.—Ice Observation Flights 3 and 4 May 1975

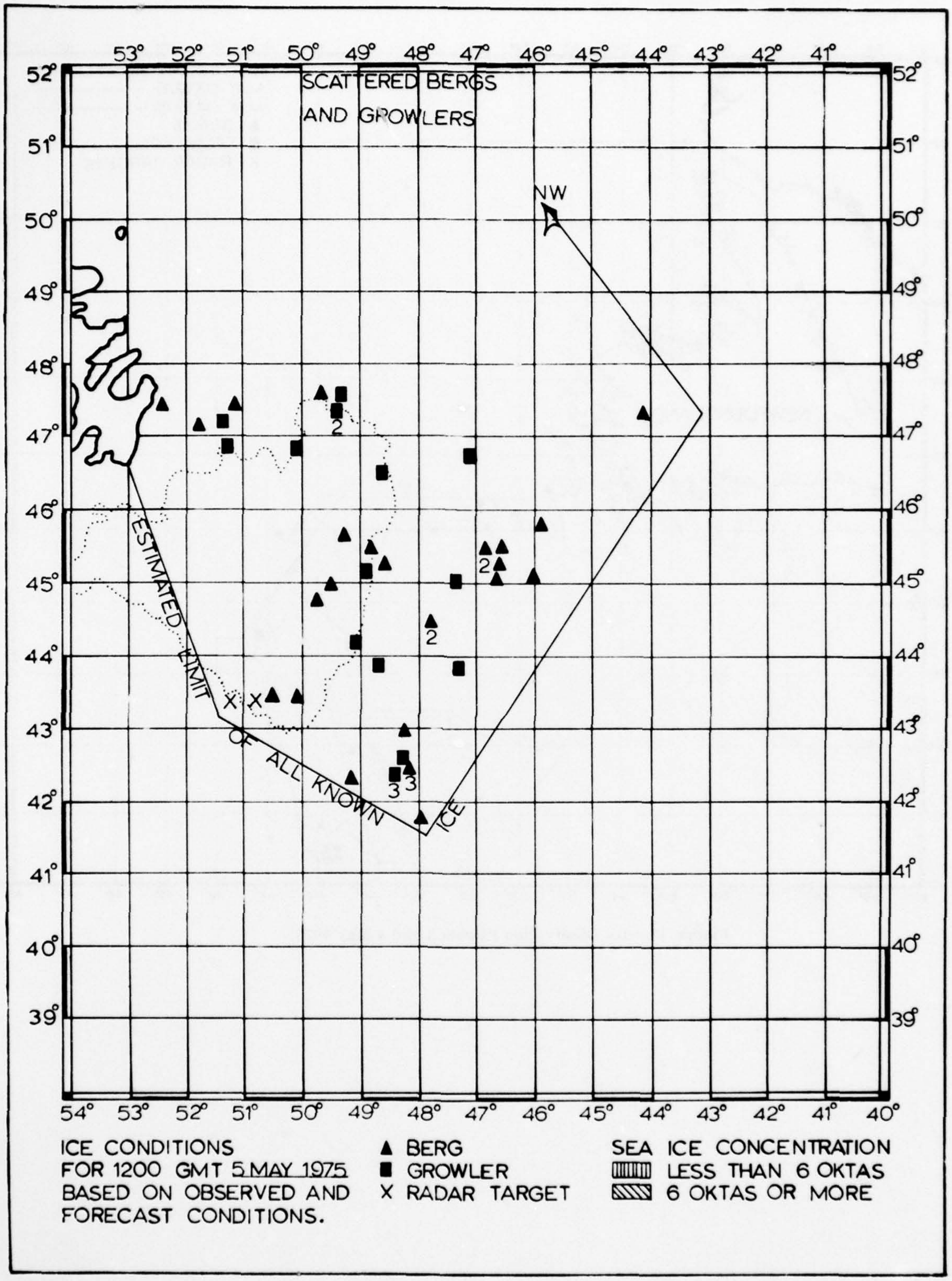

FIGURE 14.—Ice Conditions, 1200 GMT 5 May 1975

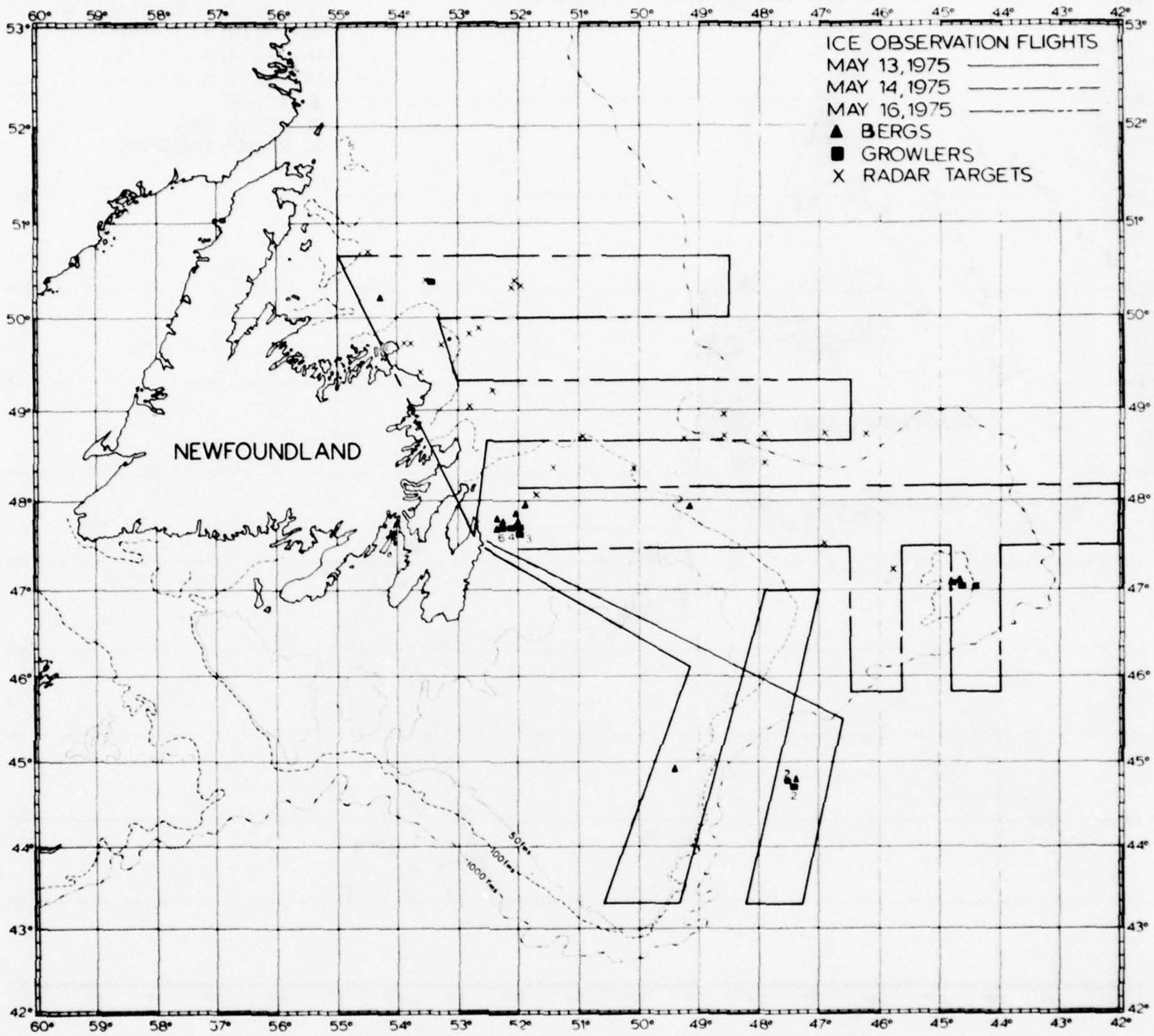

Figure 15.—Ice Observation Flights 13, 14, and 16 May 1975

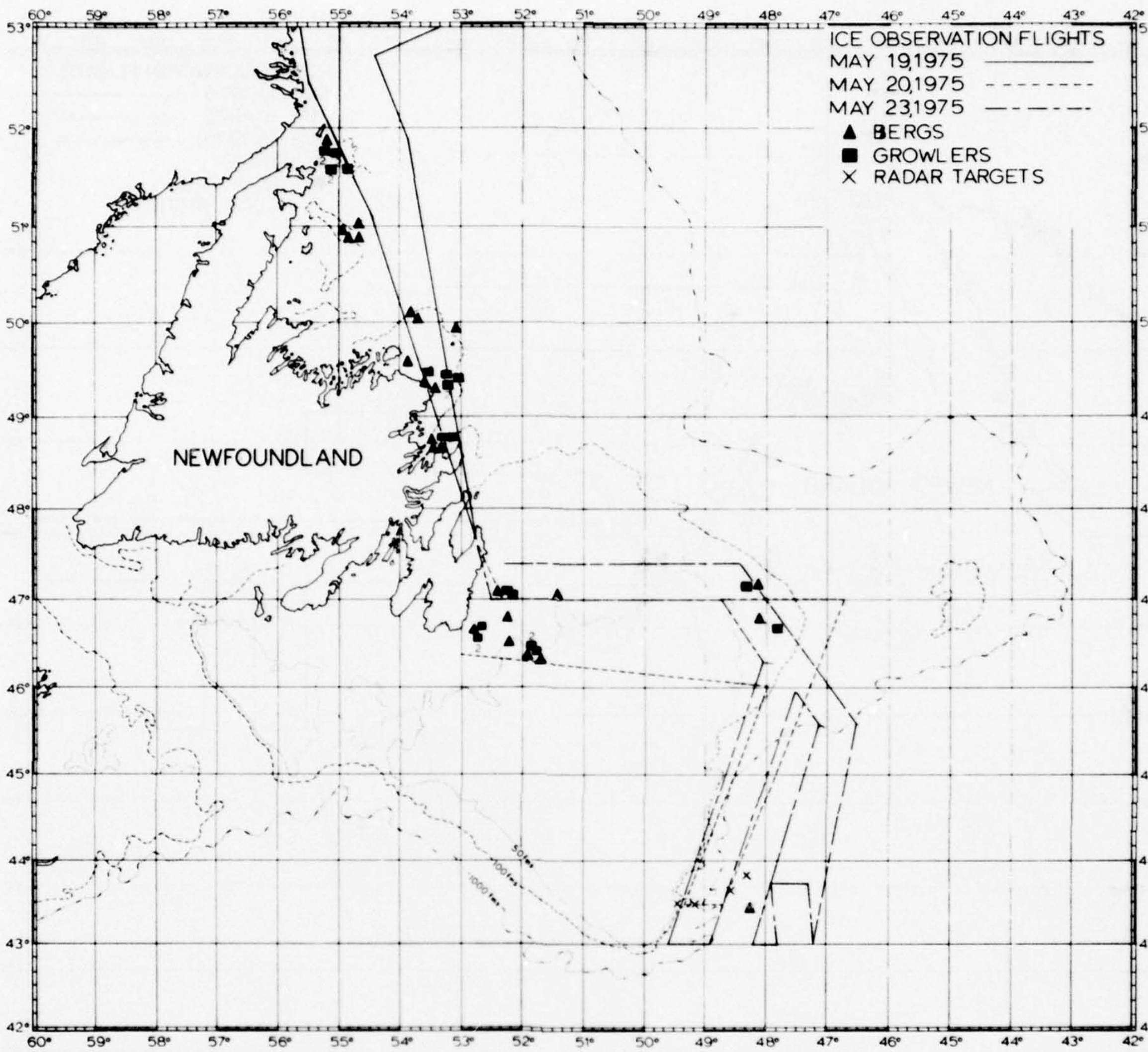

FIGURE 16.—Ice Observation Flights 19 and 23 May 1975

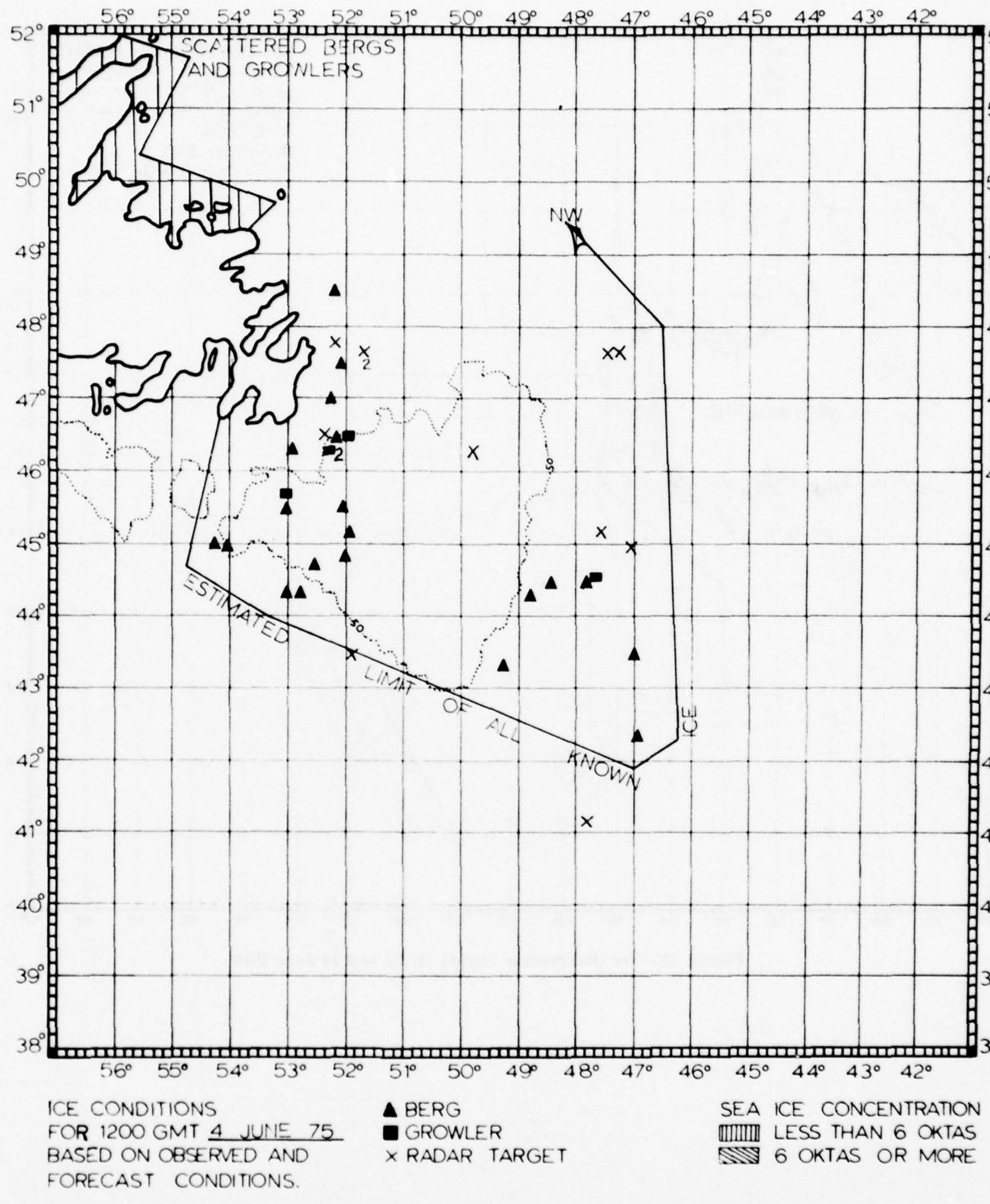

FIGURE 17.—Ice Conditions, 1200 GMT 4 June 1975

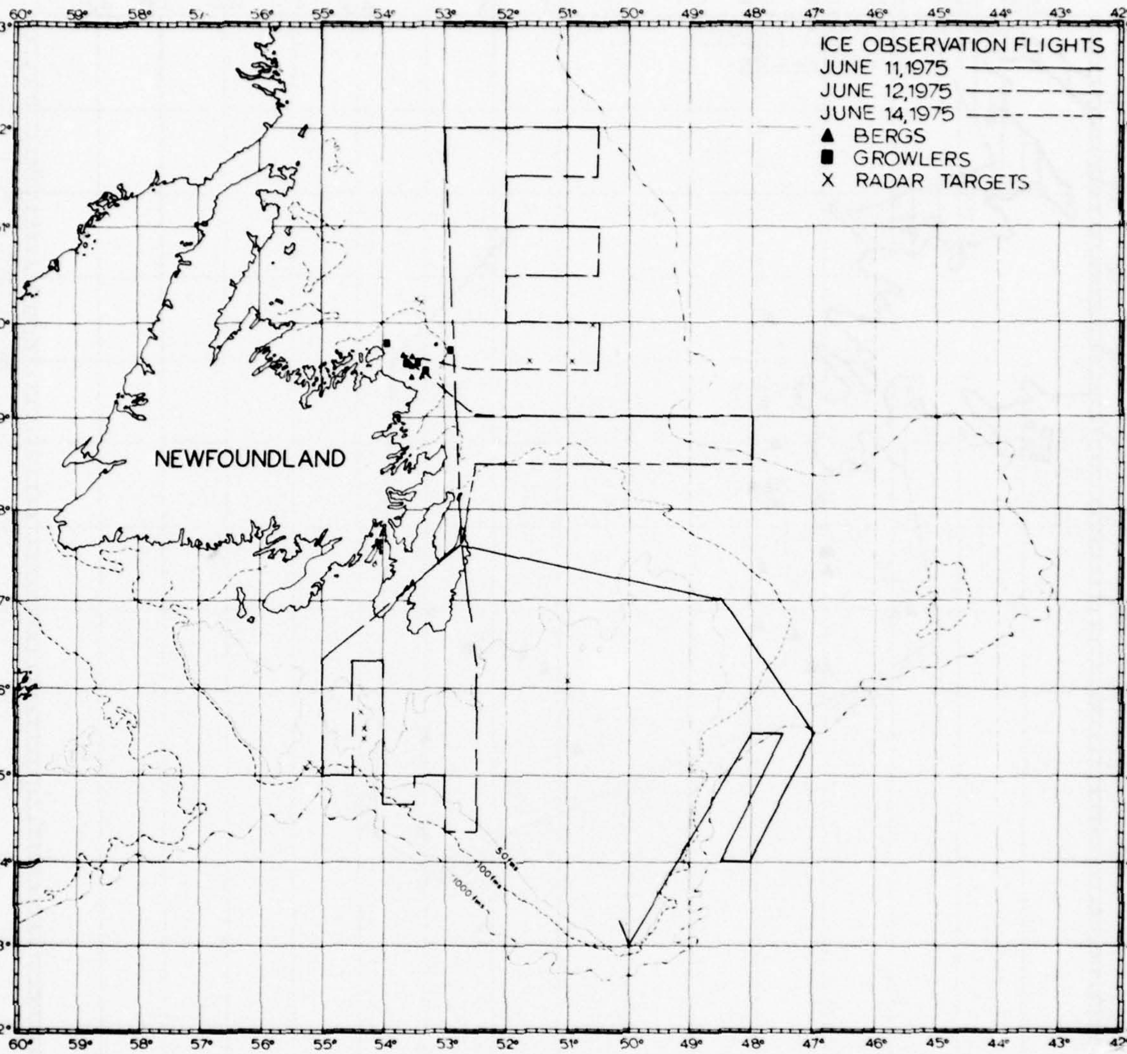

Figure 18.—Ice Observation Flights 11, 12, and 14 June 1975

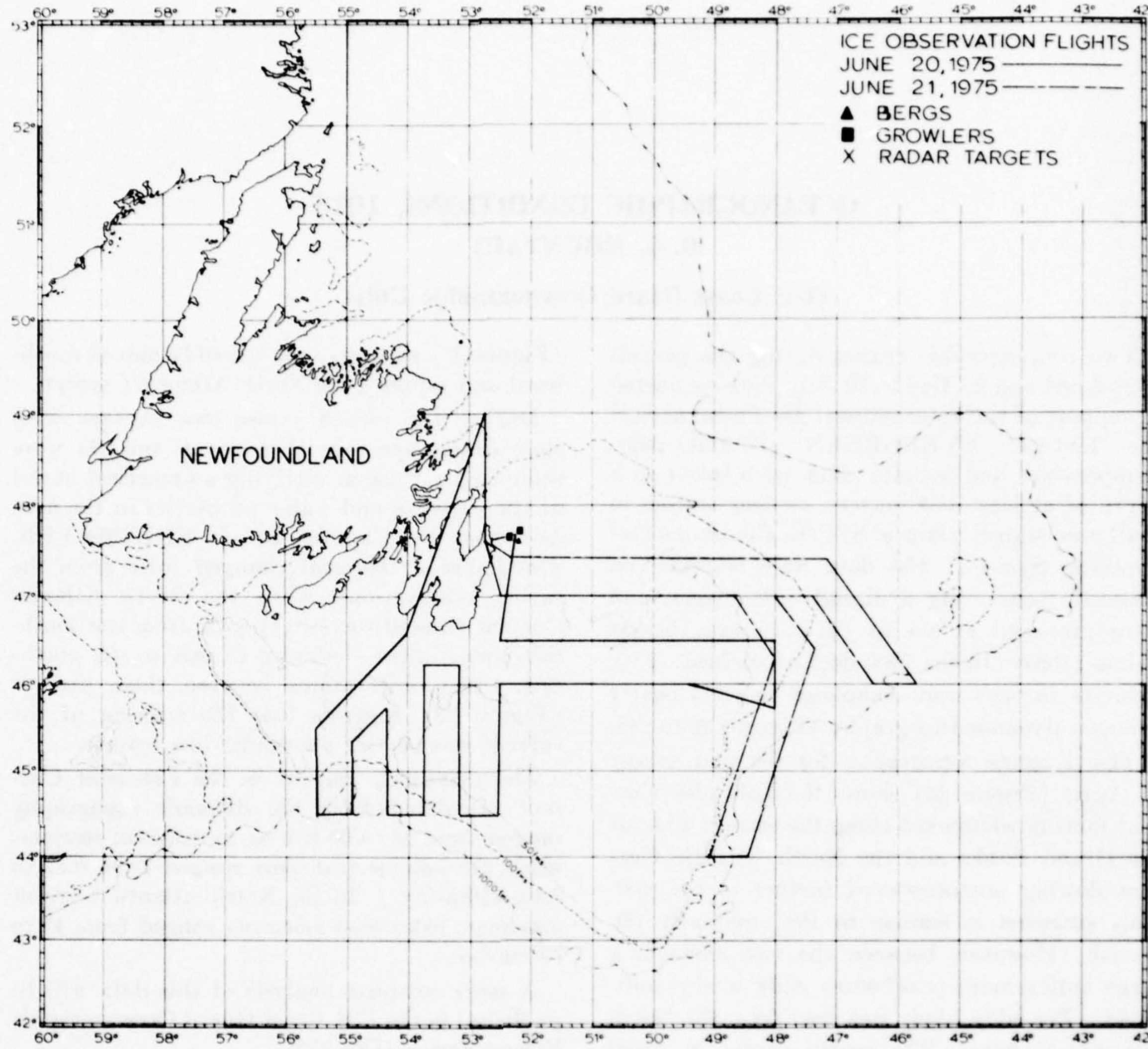

Figure 19.—Ice Observation Flights 20 and 21 June 1975

OCEANOGRAPHIC CONDITIONS, 1975

D. G. MOUNTAIN

(U.S Coast Guard Oceanographic Unit)

Two oceanographic cruises during the periods 2–29 April and 20 May to 10 July were conducted in support of the International Ice Patrol aboard the USCGC EVERGREEN (WAGO–295). Temperature and salinity data were taken to a depth of at least 1000 meters, or near bottom in shallower water, using a S/T/D Environmental Profiling System. The data were recorded on magnetic tape using a digital data logger, and were processed at sea to yield dynamic height values relative to the 1000 decibar surface. Five separate surveys were completed to yield nearly synoptic dynamic topography (Figures 20 to 24).

The dynamic topography for the first survey in April (Figure 20) shows the Labrador Current flowing southward along the eastern edge of the Grand Banks and the North Atlantic Current flowing northeastward further to the east. This situation is similar to that normally observed. However, between the two currents a large anticyclonic (clockwise) eddy is also indicated. The eddy likely was shed from the North Atlantic Current. The second survey in April (Figure 21) suggests that the eddy moved southward and rejoined the North Atlantic Current.

During the second cruise two surveys with close station spacings (Figures 22 and 24) were conducted for use in verifying a numerical model of the currents and water properties in the area developed by Captain R. C. KOLLMEYER. The Labrador Current changed little from the earlier observations, while the North Atlantic Current entered the survey area from the southeast then turned clockwise to exit to the northeast. The observations between these surveys (Figure 23) suggests that the turning of the current was part of a meander like feature.

The maximum current in the Labrador Current calculated from the dynamic topography ranged from 28 to 65 cm/sec at different sections, while the volume transport ranged from 0.77 to 7.40, $x10^6 m^3/sec$. In the North Atlantic Current maximum calculated velocities ranged from 45 to 75 cm/sec.

A more complete analysis of this data will be published in the U.S. Coast Guard Oceanographic Report Series (CG–373).

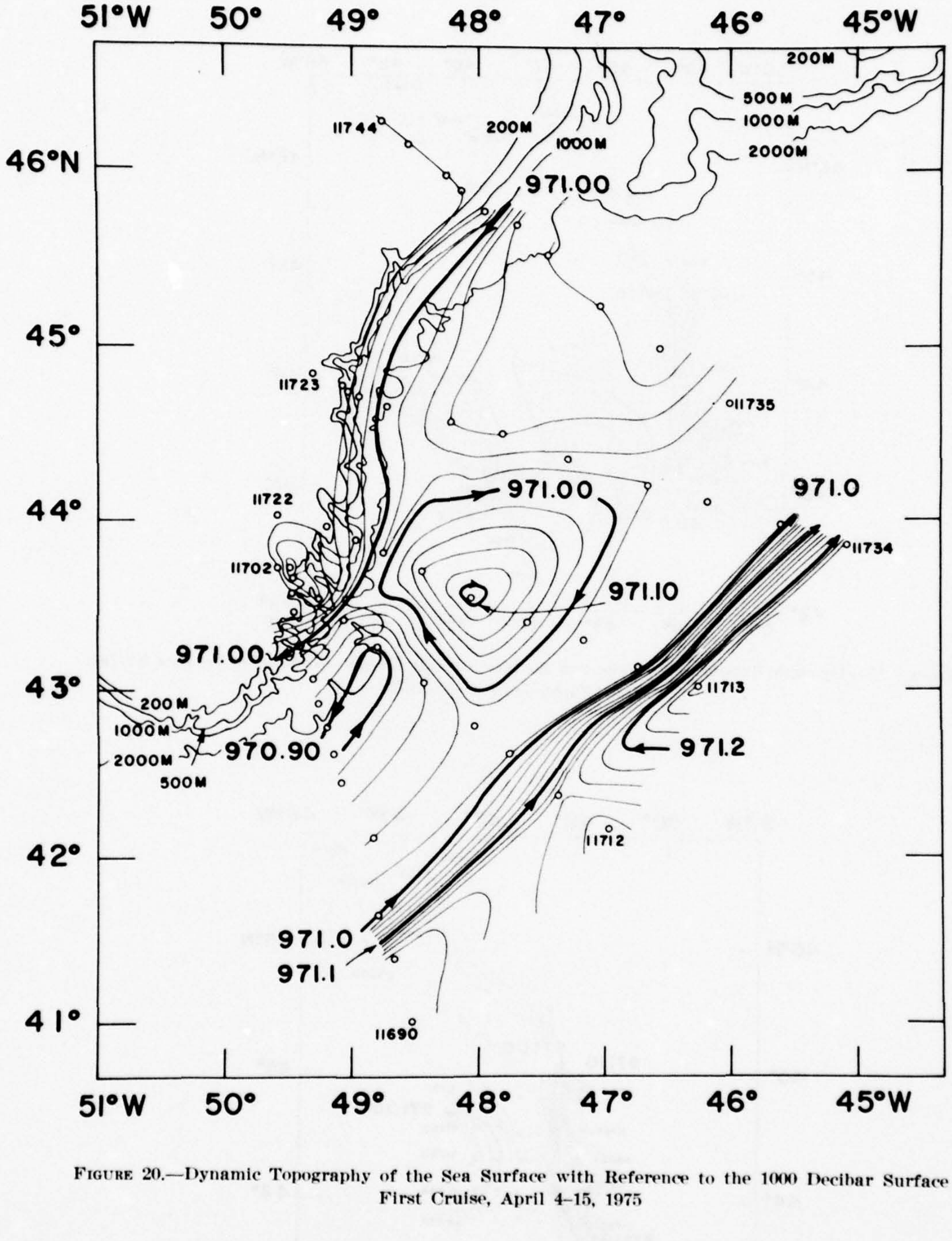

FIGURE 20.—Dynamic Topography of the Sea Surface with Reference to the 1000 Decibar Surface First Cruise, April 4–15, 1975

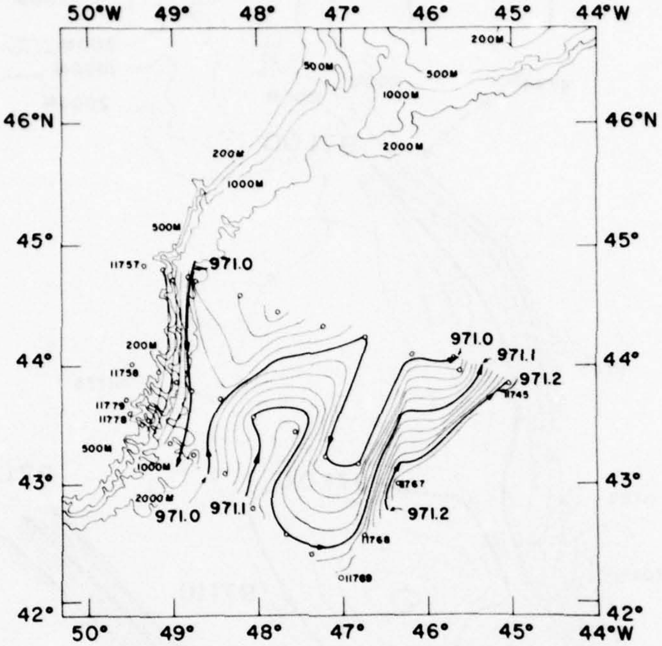

FIGURE 21.—Dynamic Topography of the Sea Surface with Reference to the 1000 Decibar Surface First Cruise, April 21–25, 1975

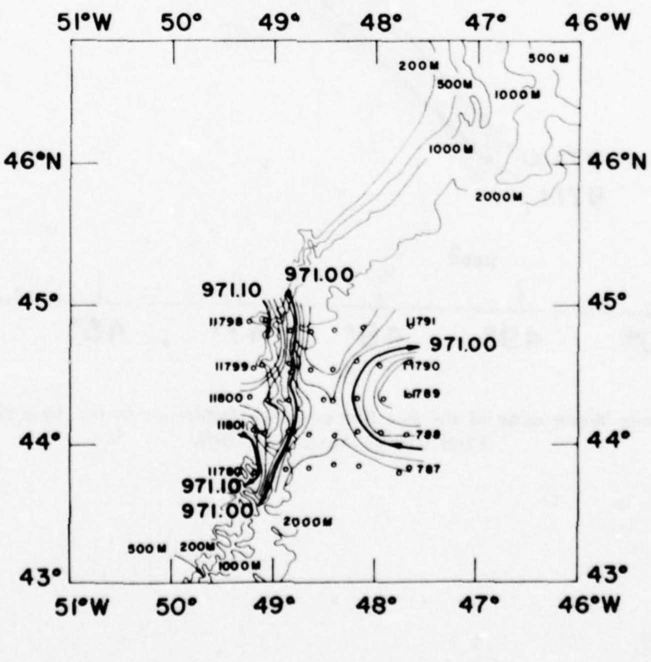

FIGURE 22.—Dynamic Topography of the Sea Surface with Reference to the 1000 Decibar Surface Second Cruise, May 26–27, 1975

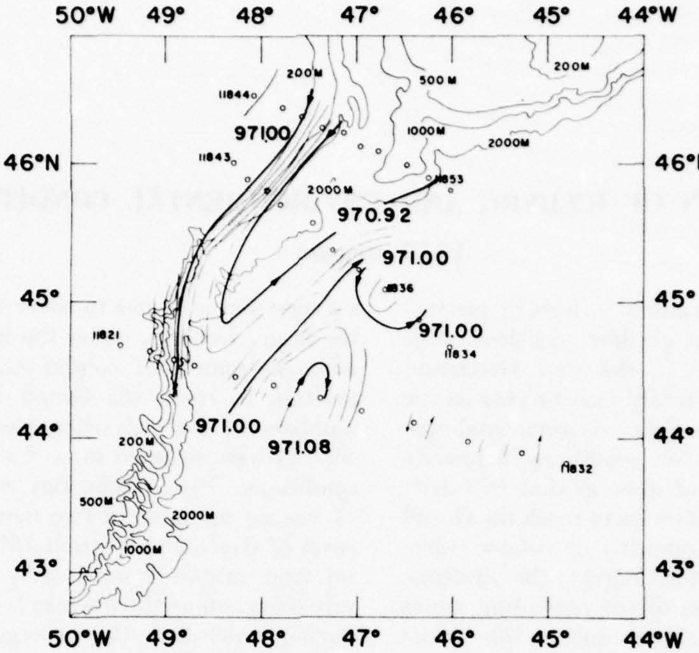

Figure 23.—Dynamic Topography of the Sea Surface with Reference to the 1000 Decibar Surface Second Cruise, May 29 thru June 1, 1975

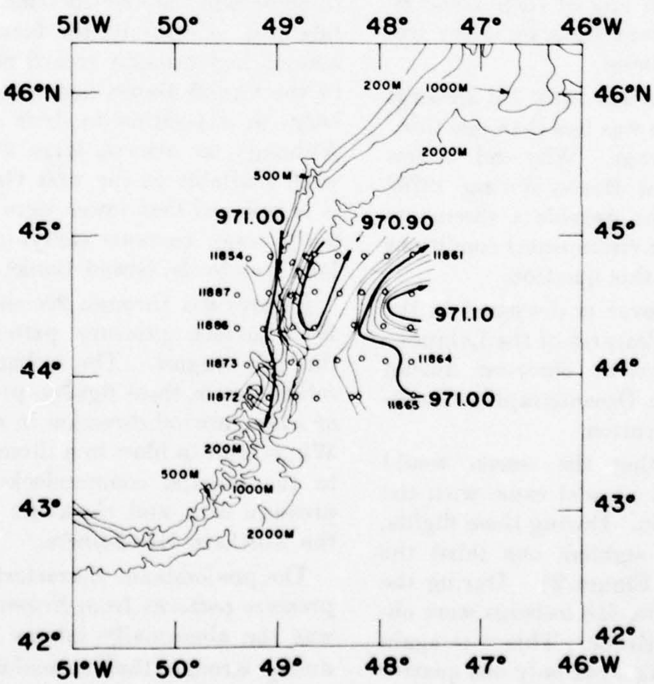

Figure 24.—Dynamic Topography of the Sea Surface with Reference to the 1000 Decibar Surface Second Cruise, June 3–6, 1975

DISCUSSION OF ICEBERG AND ENVIRONMENTAL CONDITIONS

1975 Season

Despite annual fluctuations in iceberg productivity of the Greenland glaciers, sufficient bergs are normally available in the west Greenland inventory to produce a record iceberg year on the Grand Banks, given the right environmental conditions. Four factors or conditions primarily determine the number of icebergs that will drift toward and ultimately survive to reach the Grand Banks. These are the intensity or volume transport rate of the Labrador Current; the direction, magnitude and duration of the prevailing winds encountered by the icebergs during this drift; the extent of the sea ice cover available to protect the icebergs; and, finally, the environmental conditions to which the iceberg is exposed when out of sea ice (i.e., air and water temperatures, wave action). Abnormalities in any of these could be responsible for either a very light or heavy iceberg season off Newfoundland.

The 1975 iceberg season saw only 101 icebergs cross 48°N latitude. This was less than one third of the 1946 to 1974 average. Why did so few icebergs reach the Grand Banks during 1975? The following paragraphs provide a discussion of the 1975 iceberg and environmental conditions in an attempt to answer this question.

This season's sea ice cover is discussed in the Ice Conditions section. Features of the Labrador and North Atlantic Current observed during 1975 are reviewed in the Oceanographic Conditions section of this publication.

The first indication that the season would probably be lighter than normal came with the January preseason mission. During these flights, only 336 icebergs were sighted, one third the 1963–1974 average (See Figure 2). During the February preseason flights, 518 icebergs were observed south of 67°N latitude. This was again about one third the average, but only one quarter the number normally encountered between 62°N and 67°N latitude during late February (See Figure 4). The track lines for both of these surveys were selected to cover those areas where the larger icebergs, under the influence of favorable environmental conditions, would be in a position to reach the Grand Banks. The low numbers of icebergs encountered during these surveys were believed to be due primarily to two conditions. First, Baffin Bay was essentially free of sea ice for most of two months and the west coast of Greenland south of 75°N was free of sea ice from mid-July until early November. This was some two or three weeks longer than normal, during which time the icebergs were exposed to open water. Secondly, a deeper than normal Icelandic low during the late fall created higher winds and thus more turbulent seas off the middle west Greenland coast. These factors combined to accelerate the deterioration rate of icebergs in this area. Certainly, the fact that the last three seasons had brought record numbers of icebergs to the Grand Banks had some effect on the icebergs in a position to drift south during 1975. Although, as always, large numbers of icebergs were available in the west Greenland inventory, it is believed that fewer were near or in the primary ocean currents carrying icebergs on their long trek to the Grand Banks.

Figures 25a through 25e show the normal and 1975 surface pressure patterns for November through August. The isobars, shown as heavy solid lines in these figures, provide an indication of average wind direction in any particular area. Winds tend to blow in a direction nearly parallel to the isobars, counterclockwise around a low pressure area and clockwise around a high for the Northern Hemisphere.

The predominant characteristics of the average pressure patterns from November through March was the abnormally intense Icelandic low producing stronger than normal northerly and northwesterly winds south of Davis Strait along the Baffin Island and Labrador coasts. The resultant flow brought the icebergs south much faster than

normal. This was particulary true during February when the Icelandic low averaged some 17 mbs below normal.

From the extremes of February, the pressure patterns returned to near normal in March with the Icelandic low somewhat deeper and just slightly west of its normal position. This pattern produced winds more on-shore than experienced earlier in the season. April saw an intensification of this on-shore flow off Labrador as the Icelandic low spread to a broad trough extending from just southwest of Iceland to the United States' Northeast. A high dominated the Hudson Bay area at this time. These on-shore winds drove many of the icebergs aground off Labrador.

This was the primary reason that so few icebergs drifted south of 48°N during the latter part of the 1975 season.

During May, the Icelandic low appeared as a more intense feature and shifted to a position more south and west than normal. This produced northerly winds close to the Newfoundland coast and brought some icebergs south through the Avalon Channel.

As was normal, winds averaged on-shore for the remainder of the season, inhibiting any further iceberg intrusion onto the Grand Banks.

Surface pressure gradients (differences in atmospheric pressure along a geographically oriented line) provide an indication of wind velocities that exist in the area. The steeper the gradients or more rapid the pressure change, the higher the wind speed will be. In an attempt to understand the magnitude and primary direction of winds along the main drift routes of the icebergs heading toward the Grand Banks, six such gradients have been defined by the Ice Patrol for Davis Strait and off the Newfoundland and Labrador coasts. (See Figure 21). From an analysis of these gradients, inferences can be made as to the northwesterly winds producing southerly iceberg drift, accentuating the Labrador Current, reducing the air and sea temperatures, and spreading and developing sea ice along the coasts of Labrador and Newfoundland.

Gradients assigned numbers 1 and 2 in figure 26 measure the winds off the coast of Labrador which are important in setting up the drift for transporting icebergs to the general area northeast of Newfoundland. Gradient 3 measures the wind component which assists or impedes icebergs as they drift south along the eastern slope of the Grand Banks. Gradient 4 is a measurement of the influence of westerly (or easterly) winds along the northern slope of the Grand Banks. This is important in determining iceberg drift away from (or toward) the Newfoundland coast and into (or out of) the core of the Labrador Current. If the westerly winds are too strong or persistent when the bergs reach the northeast corner of the Grand Banks, they may be carried out over Flemish Cap and deteriorate rapidly as they are pushed into the warmer waters of the North Atlantic Current. Gradients 5 and 6 provide a preseason indication of probable icebreg drifts south and west in Davis Strait.

The 1975 pressure gradient data are shown graphically in figures 27 and 28 with a comparison provided to their 1946–1974 normals. The most obvious and significant features in these gradients are the high peaks that occurred in gradients 1, 2 and 3 during January and February. These peaks indicate a much stronger than normal southeasterly wind drift accounting for the relatively large numbers of icebergs reaching the Grand Banks early in the season. Likewise, northerly flow and below normal southerly flow indicated in gradients 3 and 2 respectively during March and April help to explain the decreased influx of icebergs during the early spring. South winds across gradient 3 during this period also brought warm air into the area accounting for the retreat of the sea ice in late March and April as discussed earlier in the Ice Conditions section. Slightly above normal easterly flows early in the season, as indicated through gradient 4, kept the icebergs offshore during this period.

Air temperatures over Labrador and east Newfoundland waters were predominately 1° to 6°F below normal throughout the ice season. The exception was February, when temperatures averaged 6° to 13°F below normal. This month was recorded as the coldest on record east of Newfoundland. Graphic presentations of cumulative frost degree days and melting degree days are provided in figures 29 and 30 for selected shore stations along Canada's east coast. The locations of these stations are shown in figure 26. A frost degree day is defined as one day mean temperature of one Fahrenheit degree below 32°

(e.g., one day at 20°F would equal 12 frost degree days). Similarly, a melting degree day is one day mean temperature of one Fahrenheit degree above 32°. All stations had greater than normal accumulations of frost degree days during 1975, but also, with the exception of Hopedale, had a near normal or above normal accumulation of melting degree days by the end of July.

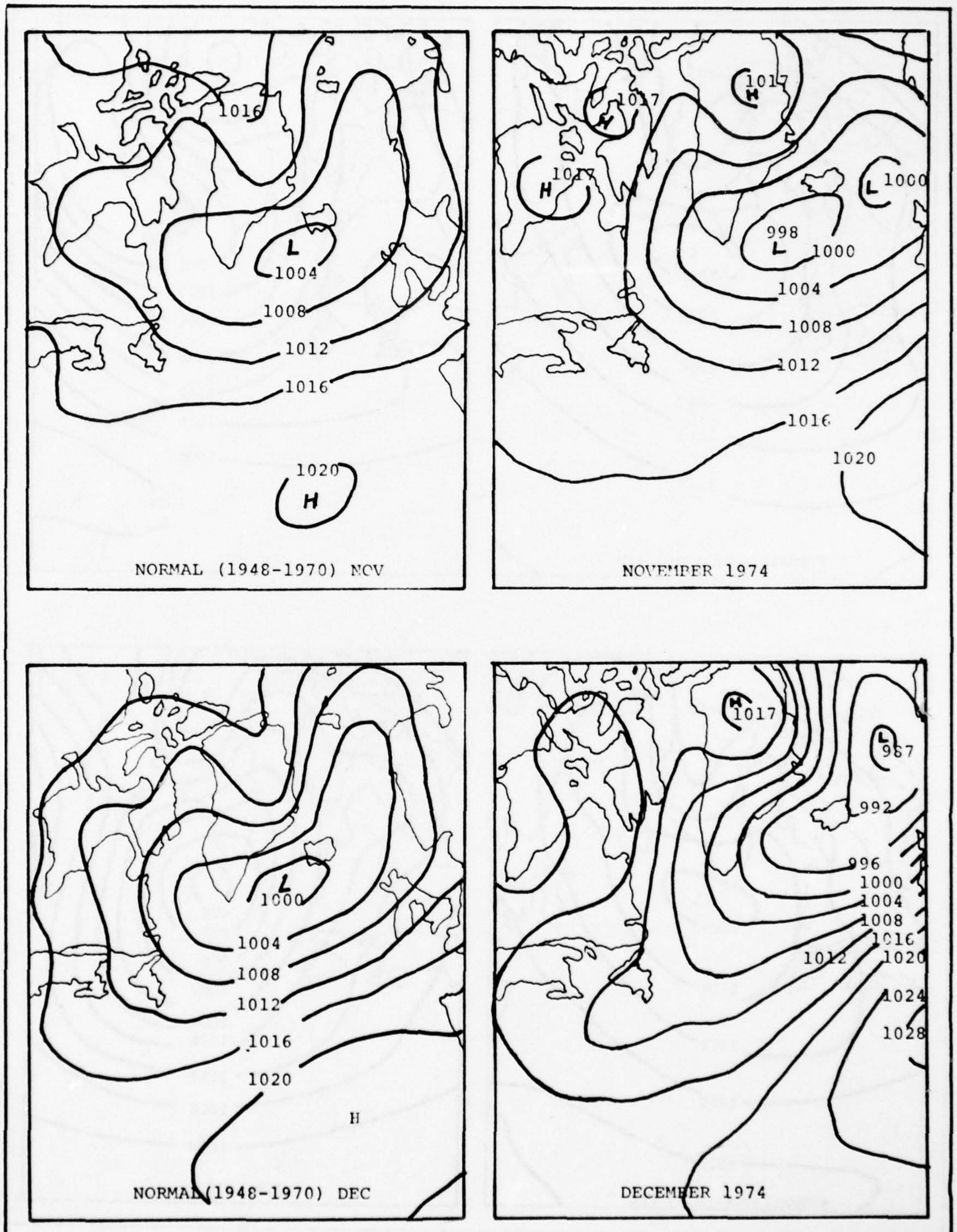

FIGURE 25A.—November and December Normal and 1974 Monthly Average Surface Pressure in mbs Relative to 1000 mbs

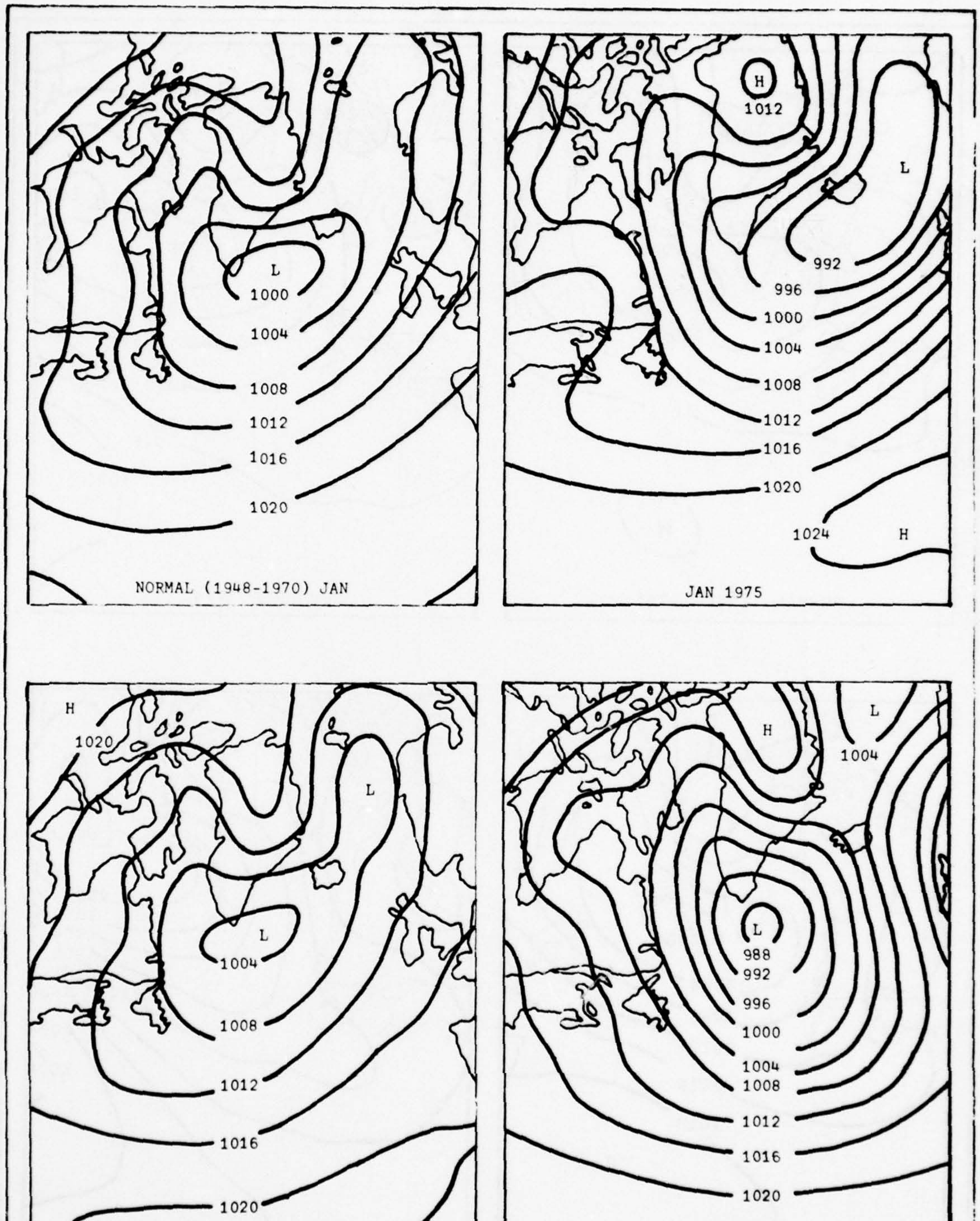

FIGURE 25B.—January and February Normal and 1975 Monthly Average Surface Pressure in mbs Relative to 1000 mbs

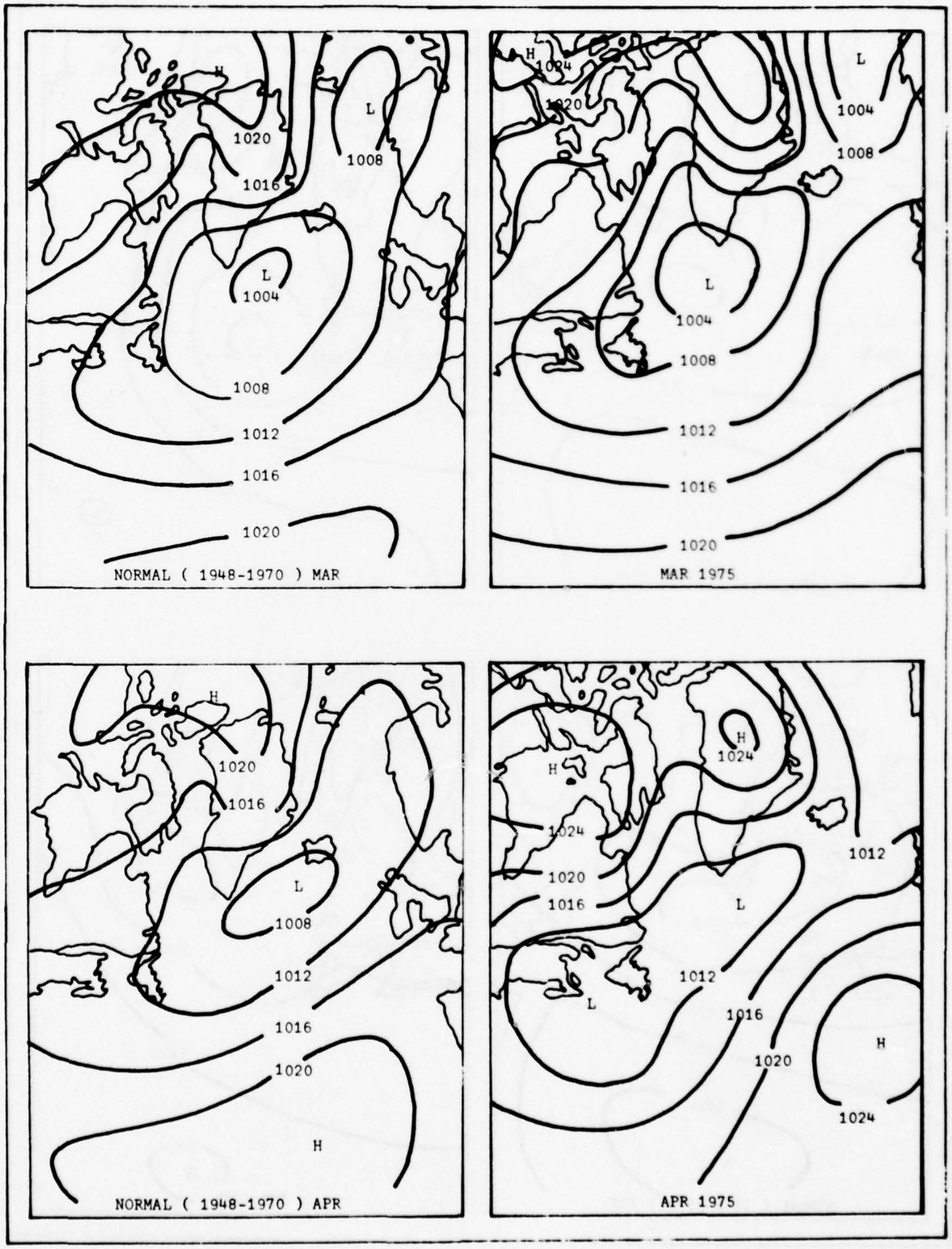

FIGURE 25C.—March and April Normal and 1975 Monthly Average Surface Pressure in mbs Relative to 1000 mbs

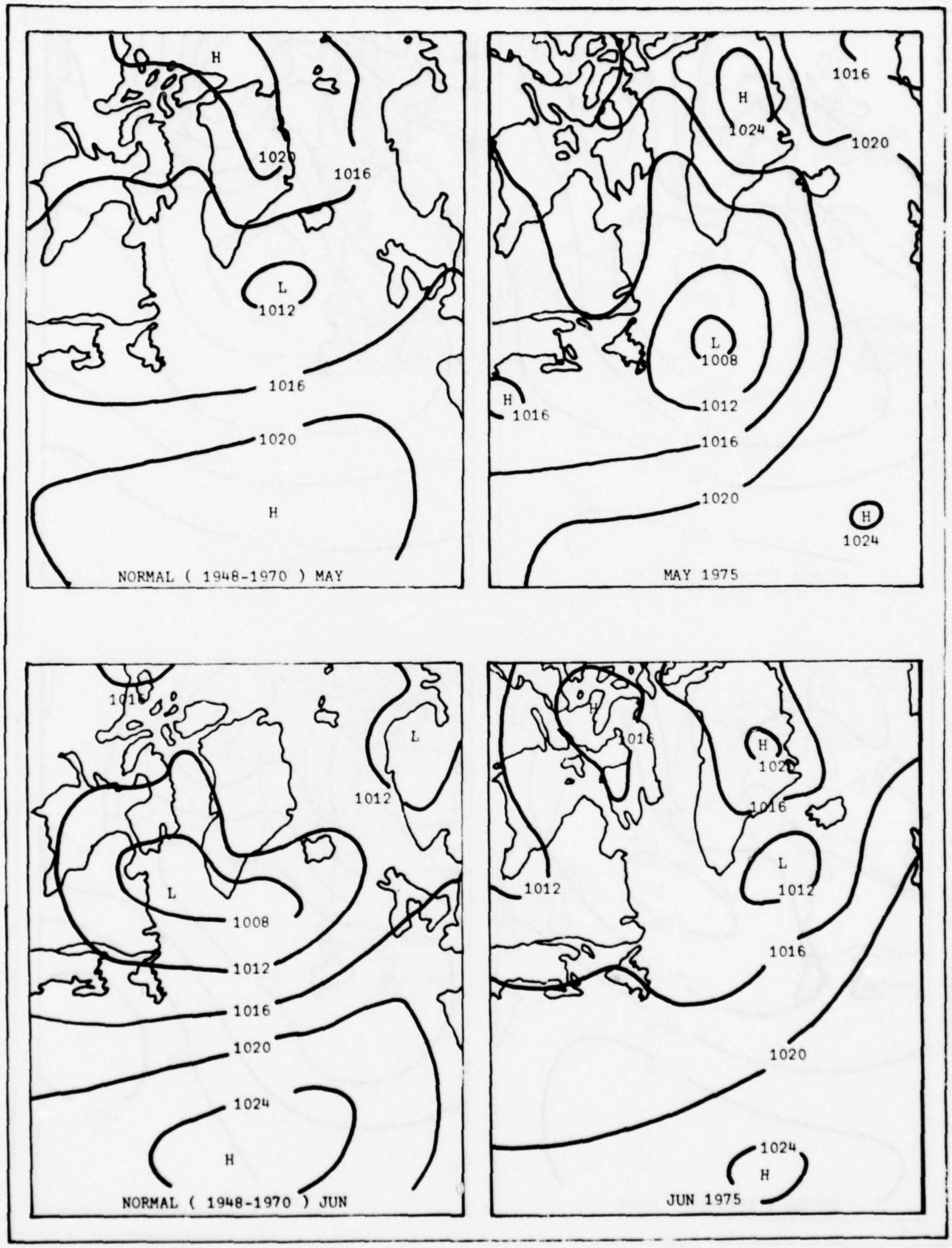

FIGURE 25D.—May and June Normal and 1975 Monthly Average Surface Pressure in mbs Relative to 1000 mbs

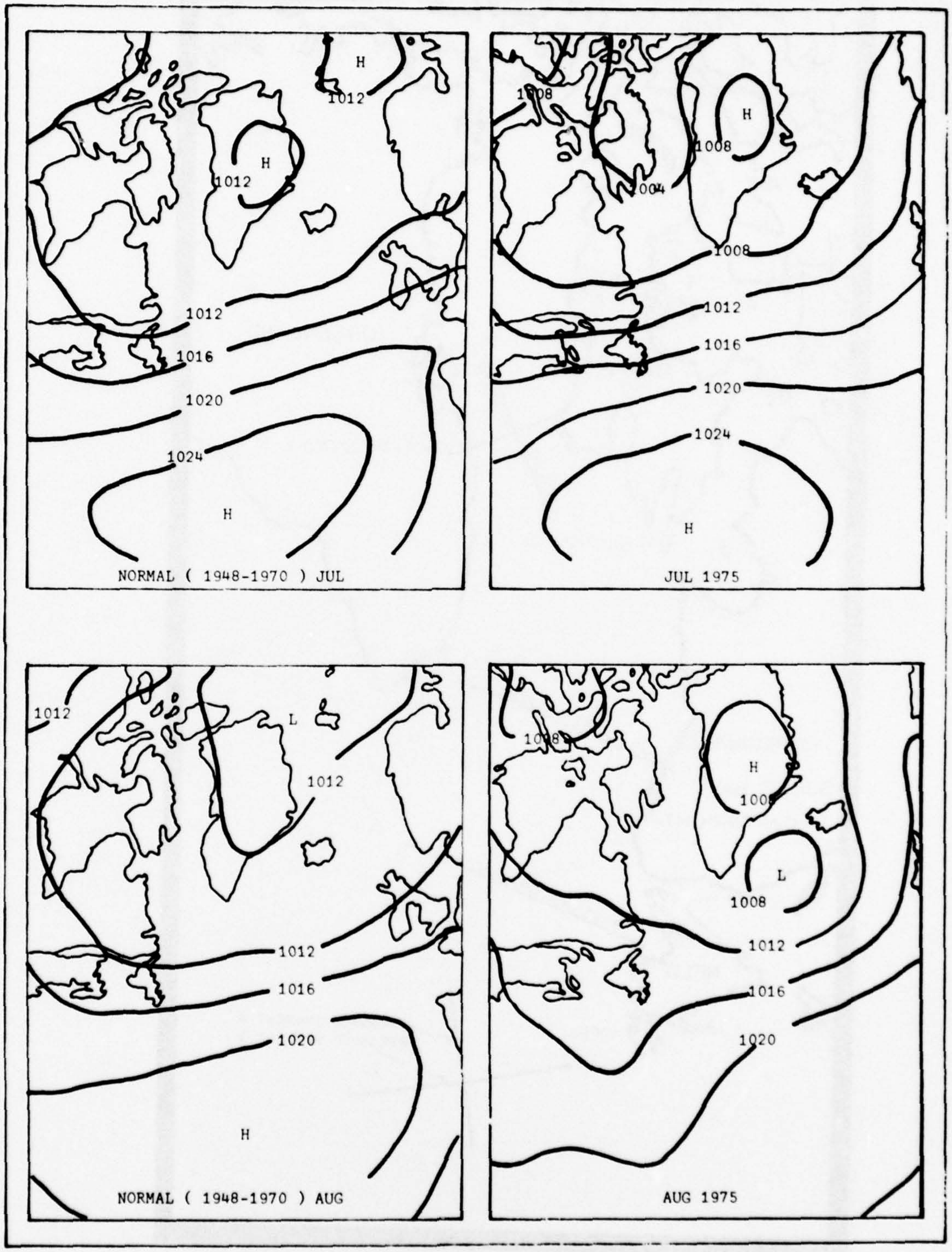

FIGURE 25E.—July and August Normal and 1975 Monthly Average Surface Pressure in mbs Relative to 1000 mbs

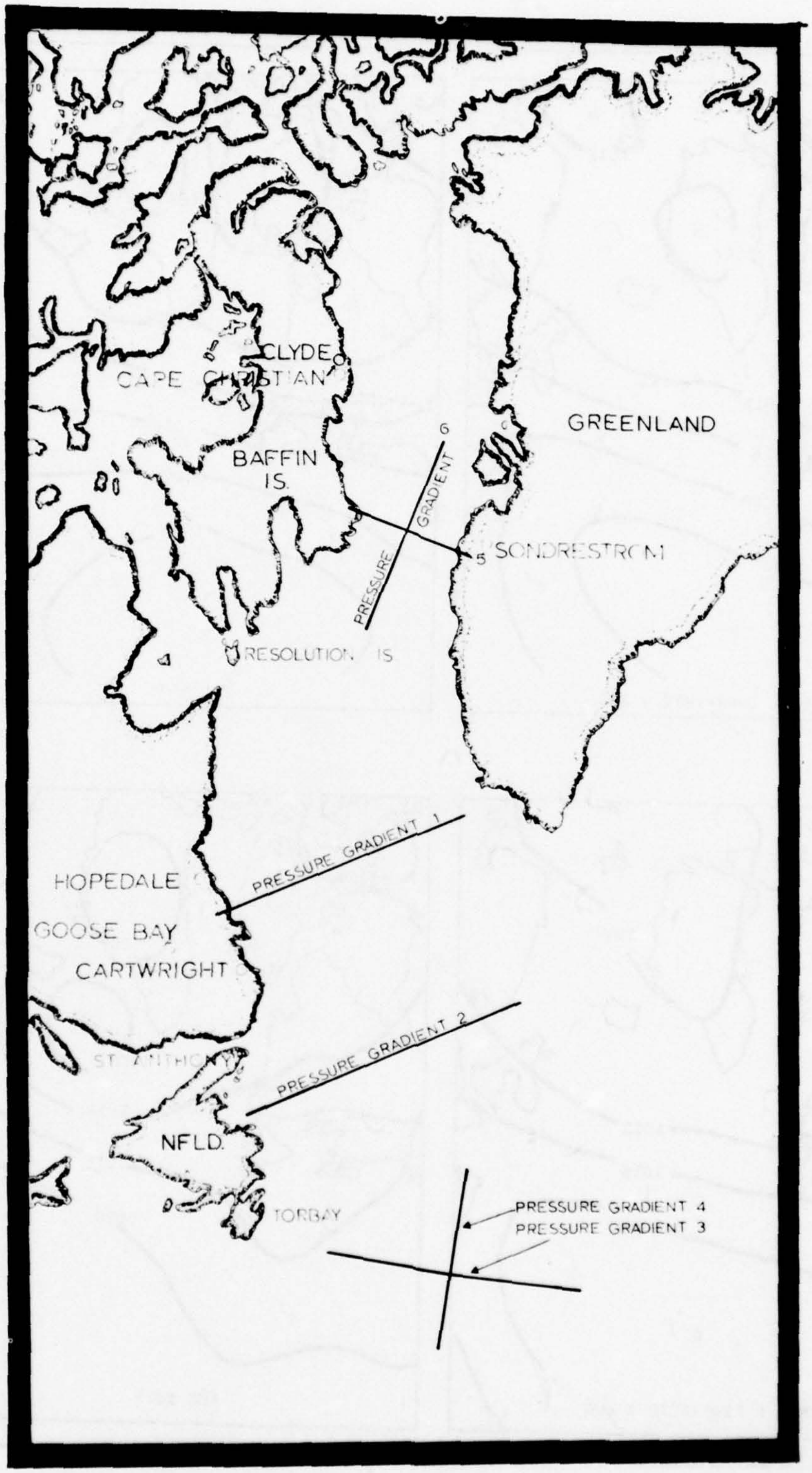

FIGURE 26.—Pressure Gradients Monitored by International Ice Patrol

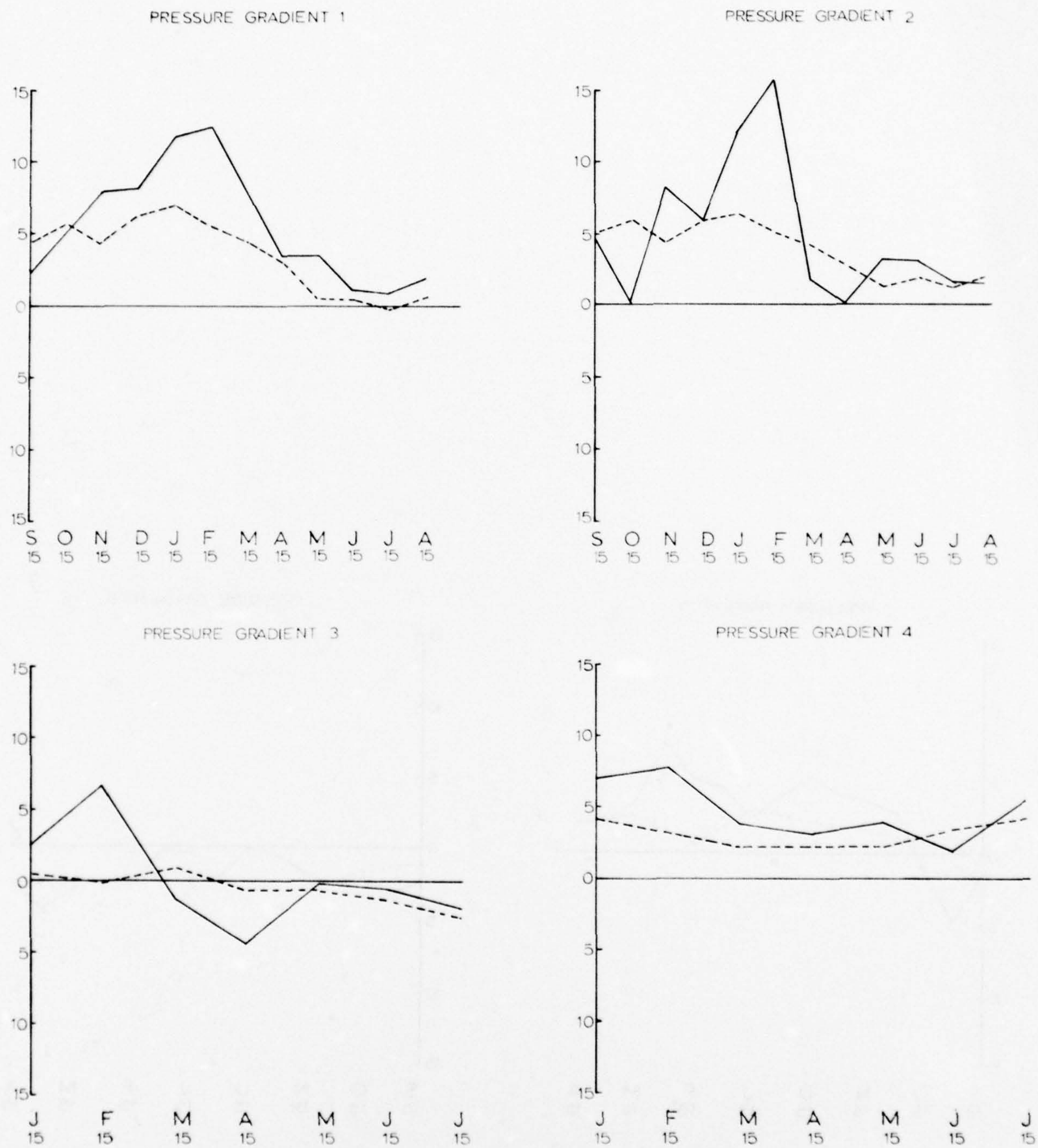

FIGURE 27.—PRESSURE GRADIENTS 1–4

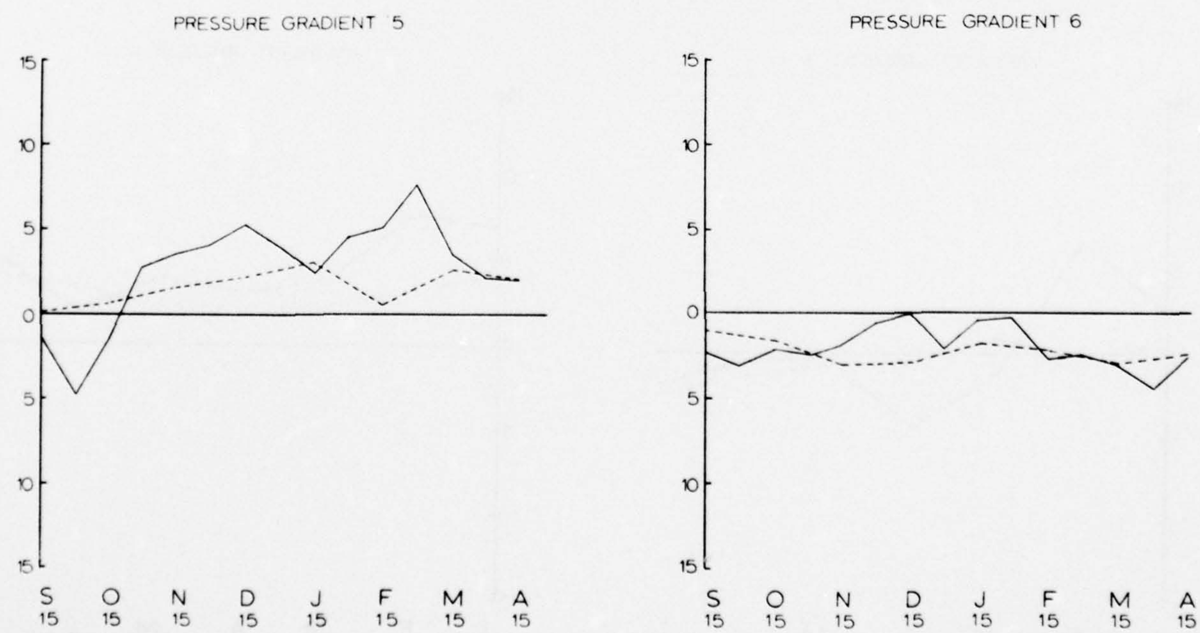

FIGURE 28.—PRESSURE GRADIENTS 5 and 6

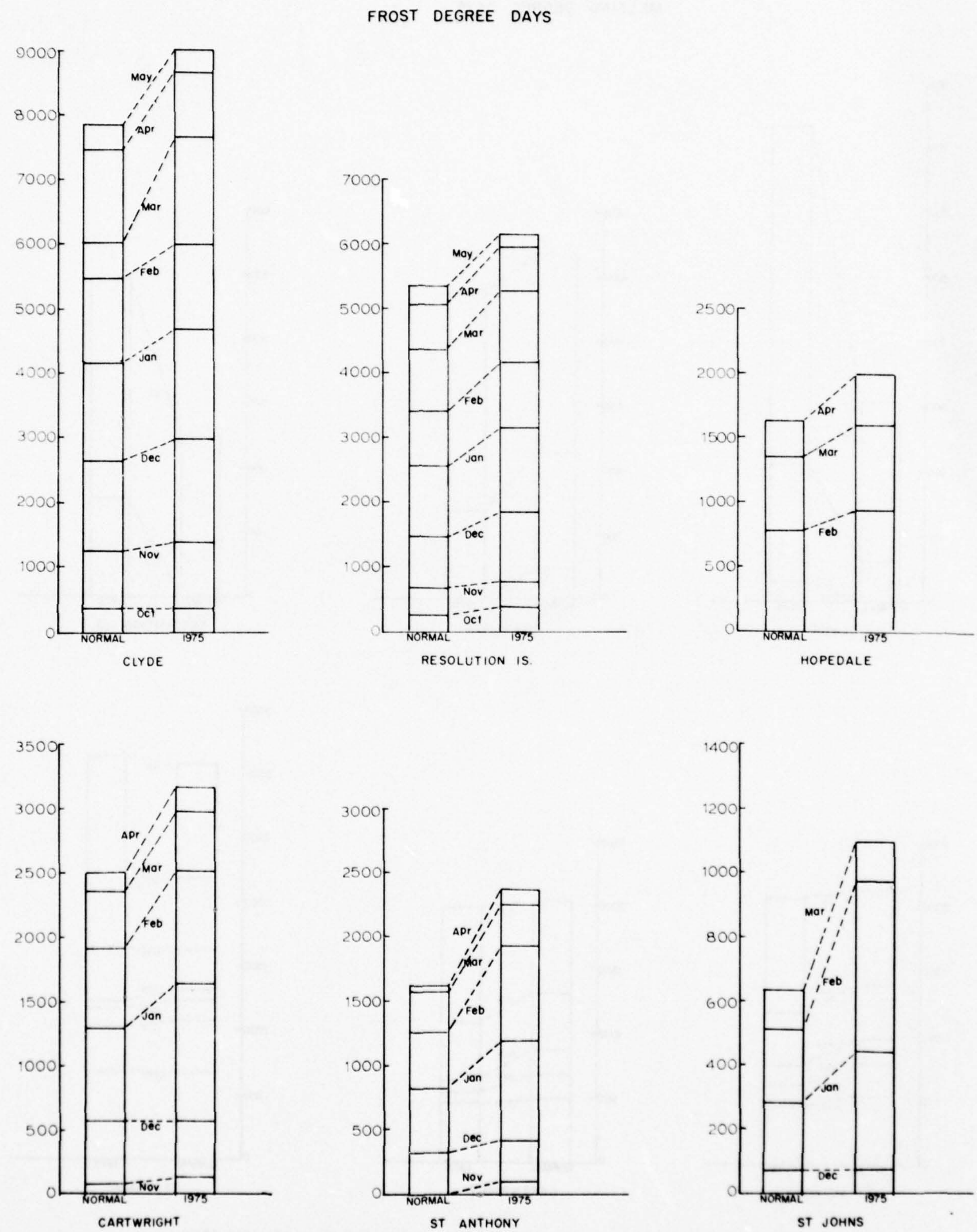

FIGURE 29.—Frost Degree Day Accumulations Calculated from Monthly Mean Fahrenheit Air Temperatures

MELTING DEGREE DAYS

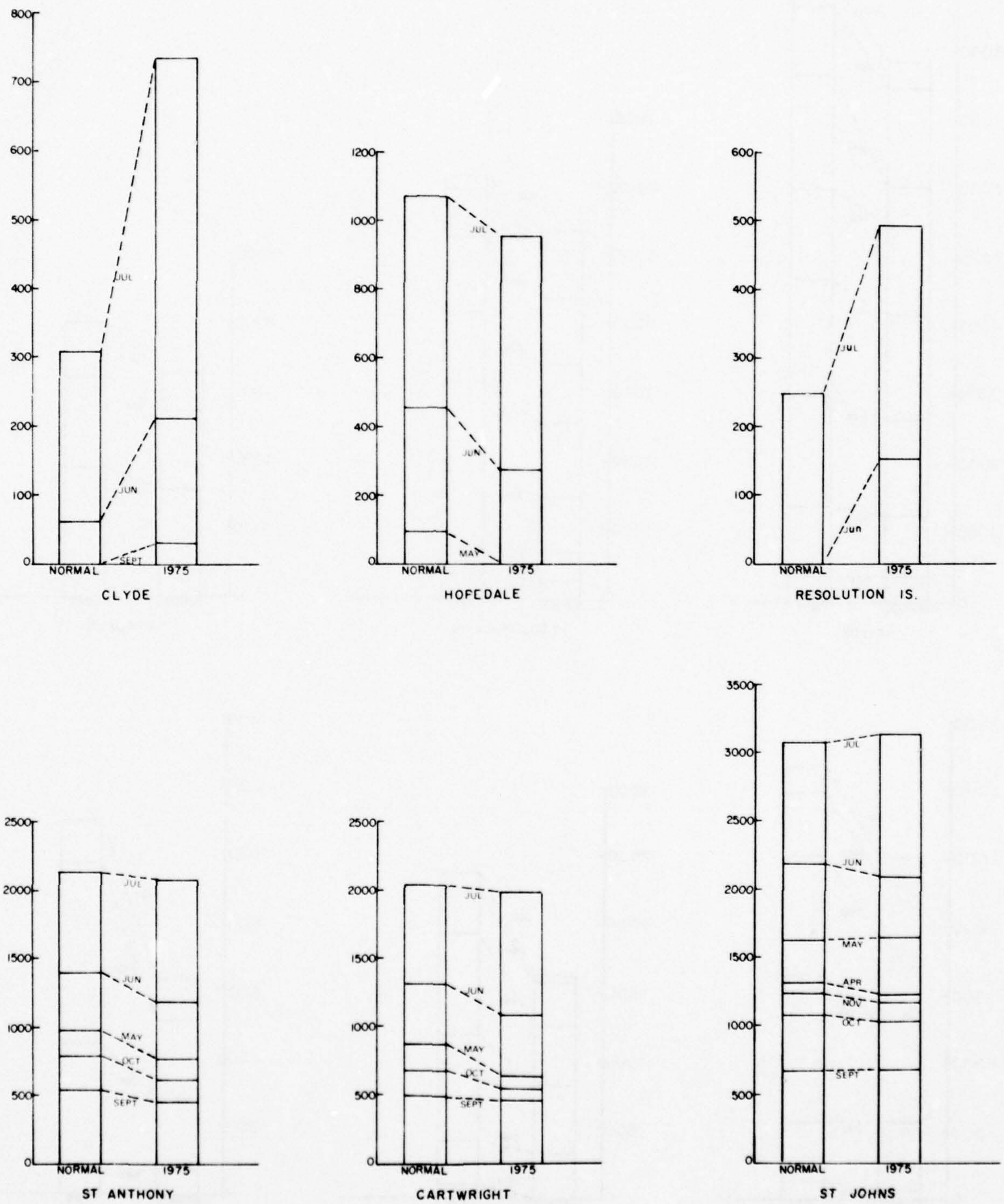

Figure 30.—Melt Degree Day Accumulations Calculated from Monthly Mean Fahrenheit Air Temperatures

RESEARCH AND DEVELOPMENT, 1975

Development of methods to tag icebergs for reidentification and drift analysis using various dye combinations continued with marginal success during the 1975 season. The natural instability of icebergs caused the dyes to be immersed and washed off. Calving would eventually result in several pieces of the original iceberg, dyed and/or clean, drifting off which would hinder identification.

An air deployed metal dart (penetrometer) was tested using the patrol aircraft and CGC SHERMAN as the surface observer. The penetrometer was thrown from the rear of the aircraft and would imbed itself in the face of the iceberg. A tag line with a wooden block was attached to the penetrometer. The surface vessel could then approach and replace the block with a transmitter for later location and identification using a direction finder. Further development of a reliable air deployable transponder would eliminate the need for a surface vessel and allow aircraft to tag icebergs on regular patrols.

Integrating current drogues were used for the first time by Ice Patrol. These drogues provided current data for iceberg drift experiments being conducted from CGC EVERGREEN. Half hourly wind data from shipboard anemometers and iceberg drifts observed visually or through ship's radar were recorded during these experiments. Empirical analysis of these data provided for increased understanding of the reaction of icebergs to the two primary forces responsible for their drift.

In April a NASA Lewis Research Center owned APS-94C Side Looking Airborne Radar (SLAR) was tested using the regular Ice Patrol aircraft to obtain simultaneous ground truth data for evaluation. Initial results indicated an outstanding target detection capability with very little target identification improvement over previous CG Research and Development Center findings. Follow on development of improved imagery interpretation is planned.

ICE AND SEA SURFACE TEMPERATURE REPORTS RECEIVED FROM SHIPS OF PARTICIPATING NATIONS DURING 1975

	ICE	*SST*
BELGIUM		
FEDERAL SCHELDE	1	
MINERAL SERAING	2	11
CANADA		
HUDSON	4	
HURON		14
JOHN A MacDONALD	1	
LABRADOR CCGS	2	
MARY B VI	1	
PROTECTEUR	2	
CHILE		
CARMEN		1
DENMARK		
CEDRELA		3
PACIFIC SKOU	1	
FEDERAL REPUBLIC OF GERMANY		
THEODOR STORM		2
WILHELM FLORIN		2
FINLAND		
COLONEL BILL	2	
FRANCE		
CETRA CARINA	1	
CETRA LYRA	1	
DELCHIM ALSACE		4
MONT LOUIS	1	
PELICAN	1	
SIBELIUS	2	1
GERMAN DEMOCRATIC REPUBLIC		
ANTARES	1	
ATLANTIC CINDERELLA	1	
MELLUMERSAND	2	5
MOSEL EXPRESS	2	
OTTO PORR		1
PEGASUS	1	

	ICE	*SST*
STADT BREMEN		12
STADT WOLFSBURG		11
TILLY RUSS		1
GREAT BRITAIN		
ARCTIC TROLL	1	
ATLANTIC CAUSEWAY	1	
CAST BEAVER	4	
C.P. DISCOVERER	2	
C.P. VOYAGEUR	2	
DART AMERICA	3	
DART ATLANTIC	1	
DUKES GARTH	1	
GLENPARK	2	
LAURENTIAN FOREST	3	
LONDON PRIDE		11
LONDON TRADITION	1	13
MANCHESTER CHALLENGE	5	5
MANCHESTER CONCORDE	3	1
MANCHESTER COURAGE		1
MANCHESTER CRUSADE		1
MANCHESTER QUEST	1	1
MANCHESTER ZEAL	1	
MOUNT EDEN		1
NORDIC PATRIOT	1	1
NORSE FALCON		6
ORIANA	1	
QUEEN ELIZABETH II	4	
TEXACO GHENT		4
TIDEFLOW	1	
TROLL PARK	5	
WELSH MINSTREL		2
GREECE		
ATHINAI		2
ARISTEES	1	
AVAX	1	
DRYMAKOS	1	
FEDERAL SEAWAY	1	
FODELE		3
JULIA LI		1
NORTHERN FROST	1	
PHILIPPA		1
STALO 2	1	1

	ICE	*SST*
ICELAND		
BRUARFOSS	1	
GODAFOSS	1	
SKAFTAFELL	1	
INDIA		
ANCOJYOTI	1	1
ATHELLAADKI		1
GAUTAMA BUDDA		1
JALAMOKAMBI	2	5
RATNAKIRTI		2
VISHVA KALYAN	1	
ITALY		
GIOVANNI AGNELLI	1	
SIRIO	1	1
TITO CAMPANELLA		2
JAPAN		
DAITOKU MARU	3	
TOYAMA MARU	1	
LIBERIA		
DELAWARE	1	
JOHANN SCHULTE	2	
MIDIGIRL		1
MORVEN	1	
OLYMPIC PROGRESS	2	5
RIO MACAREO	1	
UNIVERSE DEFENDER	1	1
MALAYSIA		
SCOL INDEPENDENT		4
NETHERLANDS		
AMSTELHOF	2	6
ATLANTIC CROWN	1	
ATLANTIC STAR	1	
CHIRIQUI		2
HOLENDRECHT	1	
MOORDRECHT	1	
NORWAY		
BERGE SIGLION	1	
BOW ELM	1	1
FOSSUM	1	
GEIRA	1	
HAVKATT	1	
IBEFJORD	1	
JOBOY	1	1
JOHN KNUDSEN		4
KIWI ARROW	3	
LIVANITA	1	3
ROSS ISLE	2	
TEAM GERWI	1	4
PANAMA		
HOLMA	1	
POLAND		
STASZIC	2	
STEFAN BATORY	1	
ZAWIERCKE	1	
SPAIN		
ERMUA	1	
LUJUA	1	
SWEDEN		
ATLANTIC SPAN	17	26
FORESTLAND	1	1
MONT ROYAL	2	2
SEGERO		3
UNITED STATES OF AMERICA		
AMERICAN ACE	1	
AMERICAN ARCHER	1	
AMERICAN LEGEND	1	
UNITED STATES COAST GUARD		
USCGC CHASE	2	
USCGC DEPENDABLE		2
USCGC DURABLE		1
USCGC EVERGREEN	30	790
USCGC NORTHWIND	1	
USCGC SHERMAN	2	49
UNITED STATES NAVY		
USNS MIRFAK	1	
USNS NEPTUNE	1	7
U.S.S.R.		
BRYANSKIY MASHINOSTROITEL	1	
KARCHAYUO CHERKESYA	1	
PIONEER ODESSY	1	
PIONEER VOLKOV	1	
RYBATSKAJA SLAVA	1	
YUGOSLAVIA		
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APPENDIX A

THE AVIATION HISTORY OF THE INTERNATIONAL ICE PATROL

By LTJG S. R. Osmer, USCG

"It seems to me a splendid practical use can be made of aeroplanes of the type which flew across the Atlantic, the NC type of plane. Two of these, one being for a relief vessel stationed at Trepassy Bay, Newfoundland, could with practically no trouble at all make a flying observation of the Banks and locate reported and unreported bergs during the short periods of clear weather, when a vessel of the type used on patrol could cover but a tenth of the distance and be further hampered by weather conditions at the surface."

CAPT. H. G. FISHER, USCG
Senior Officer
Summary of the Ice Patrol
Season of 1919

The 1975 Season marked the thirtieth anniversary of Ice Patrol aerial reconnaissance and surveillance. This was also the 63rd year of the International Ice Patrol, a service which has been conducted since 1913. The impetus to found such a service was provided by the tragic sinking of the RMS TITANIC on 15 April 1912, with the resultant loss of 1,513 lives. The service has been conducted every year with the exception of the war years, 1917 to 1918, and 1942 to 1945.

History and Transition

"The cautious and well-thought-out use of aircraft to assist during periods of fine weather in searching out the region in and near the critical triangle area just north of the B tracks would seem to be one of the most promising of the fields of development that are open to the ice patrol at the present time."

Season of 1929
Some of the Ice Patrol's
Problems, and How It Attacks Them

Historically, U.S. Coast Guard and International Ice Patrol aerial surveillance could be said to have its beginning in 1931 when the Coast Guard was invited by the Aeroarctic Society to assign an officer, experienced in ice patrol service, to be a member of the scientific staff of the dirigible GRAF ZEPPELIN, especially to observe ice and oceanographic conditions during her arctic flight. Lieutenant Commander Edward H. SMITH (later to be renowned as Admiral "Iceberg" SMITH) was assigned. The cruise lasted from 24 July to 31 July 1931. Among the conclusions of this flight was aerial surveillance of ice and ice conditions held great promise for the future.

The 1946 Ice Season commenced a new kind of International Ice Patrol. For the first time aircraft were utilized for iceberg reconnaissance. The first flights were made on 6 February with a PBY-5A CATALINA from the U.S. Coast Guard Air Detachment at Argentia, Newfoundland.

The shift to aerial surveillance led to relocation of the coordinating center from the patrol vessel to Argentia where the planes were based.

The 1949 Season marked the first time these aircraft were the only reconnaissance tools utilized. This was a light year, only an estimated 47 bergs south of 48°N, that did not require the use of surface patrol vessels.

The 1951 Season was the second year aircraft operated without surface vessel assistance. This season was so light, only 6 bergs estimated south of 48°N, that one of the two PB1G's was rotated between Argentia and its home base in Elizabeth City, North Carolina. This helped keep Ice Patrol operating expenses down, an important consideration when the bill is footed by consignatory countries. Today, nineteen countries pay for the Ice Patrol based upon their shipping tonnage traversing the area and benefiting from the Service.

May 1952 marked the only mishap occurring at Ice Patrol. A PB1G, making a landing at Goose Bay, Labrador, had one landing wheel collapse, damaging the underbody of the plane. Fortunately, there were no injuries. Rather than undertake repairs at a base so remote, parts and engine were salvaged and the airframe was abandoned.

For the first time in writing, in Bulletin No. 40 INTERNATIONAL ICE OBSERVATION AND ICE PATROL SERVICE IN THE NORTH ATLANTIC OCEAN—Season of 1954, aerial ice surveillance is deemed to be efficient. This can be viewed as a prelude to the final acceptance of aircraft as the primary mode of ice observation, reducing the surface vessel to a supplement.

In 1954, unsuccessful tests were conducted with a bolometer (forerunner of the airborne radiation thermometer) for the purpose of distinguishing between berg and non-berg radar targets under conditions of poor visibility. It had been hoped to identify objects by measuring changes in the radiant heat.

In 1960, the Ice Patrol yearly bulletin title was changed from "INTERNATIONAL ICE OBSERVATION AND ICE PATROL SERVICE IN THE NORTH ATLANTIC OCEAN: to "REPORT OF THE INTERNATIONAL ICE PATROL SERVICE IN THE NORTH ATLANTIC OCEAN". As was stated in the bulletin for the Season of 1960, the former title reflected a distinction made when the patrol was conducted by ships alone. The term "ICE OBSERVATION" was used during a search for ice information; "ICE PATROL" meant that ice information was available and being broadcast. The advent of aircraft reconnaissance and remote sensors, and the integrated activities of the plane, oceanographic vessel and patrol vessel now provided the continuity of information which permitted the unqualified use of the term "PATROL". In this bulletin, it is stated that aircraft are the tools of Ice Patrol, to be supplemented by surface vessels when conditions dictate.

The HERCULES was equipped with the Doppler Navigation System for the 1963 Season. The readout presentations provided the ice observer continuous track and cross track information, greatly increasing the accuracy of iceberg positions. Maneuvers off the prescribed track, once extremely difficult to plot, could now be readily charted.

'Also during this season, an Airborne Radiation Thermometer (ART) was tested. Although the actual water temperatures recorded were considered not sufficiently reliable, the instrument was useful in detecting changes in surface water temperature, and therefore provided some help in locating the Labrador Current and its branches.

Bulletin No. 50, Season of 1964 states ". . . and the aircraft has become recognized as the primary tool for guarding the ice limits and for ice observation." This bulletin also states "Since 1949, the International Ice Patrol has recognized aircraft as the primary means for observing ice conditions and for guarding the limits of icebergs in the vicinity of the Grand Banks.'

The 1966 Ice Patrol Season, besides being the lightest and shortest on record (zero bergs south of 48°N and lasting from 1 March to 28 April), marked the third and final year that Commander, International Ice Patrol was permanently stationed at Argentia. In June, the U.S. Coast Guard Air Station Argentia and the International Ice Patrol Argentia were disestablished. The International Ice Patrol was transferred to Governors Island, New York. The aircraft were transferred to the U.S. Coast Guard Air Station, Elizabeth City, North Carolina, and would in the future deploy to Argentia when ice conditions warranted.

A passive microwave radiometer (Model AN/AAR-33), with the frequency selected for optimum ice emissivity, had been installed on one of the Ice Patrol aircraft. A full evaluation could not be conducted this Ice Season due to continuing aerodynamic problems caused by the location of the microwave antenna dome.

The radar used in conjunction with the microwave radiometer enabled the ice observers to identify radar targets as steel ships or icebergs. Though excellent correlation was obtained with this device, it could not differentiate between wooden fishing vessels and icebergs. Another major shortcoming was the swath width—essentially only a narrow band beneath the aircraft could be identified. The aircraft could not fly over every target. The microwave radiometer was used through the 1969 Season.

In February 1970, the Ice Patrol was notified that the U.S. Naval Station at Argentia would

be phased down in the spring of 1970. The Ice Reconnaissance Detachment deployed to Argentia on 17 March, then redeployed to the Canadian Forces Base, Summerside, Prince Edward Island, on 30 April. Though this base was 500 miles to the west of the iceberg area, operations were conducted smoothly due to the excellent support provided by the Canadian Forces and by remaining overnight at St. John's, Newfoundland, when good weather had been forecast for several successive days.

A Side-Looking Airborne Radar (SLAR) unit (model AN/DPD-2) was evaluated commencing with the 1971 Season. It was hoped that SLAR would provide an all-weather detection device. Unfortunately, this was not the result, in this case mainly due to problems associated with the obsolescence of this particular unit. The evaluation concluded at the end of the 1973 Season.

The 1972 and 1973 Seasons were the first times since 1951 that a surface patrol had to be used to supplement aircraft due to the heavy ice conditions.

The 1973 Season saw the first use of the Inertial Navigation System (INS) in the reconnaissance aircraft. The system has been a most welcome addition, providing better accuracy for iceberg plotting.

St. John's, Newfoundland, became the base of operations for the 1974 Season. This move from Summerside resulted in a drastic reduction of enroute time to the area, with a corresponding increase in on-scene time.

An ART unit was evaluated in the latter part of the 1974 Season. The information provided showed great promise for real-time temperature data for iceberg deterioration and possibly for identifying the features of the Labrador and North Atlantic Currents.

In 1975 a newer SLAR model was evaluated. Though the final analysis of the data is not yet available, the conclusion probably will be that SLAR will enhance Ice Patrol but is not the final answer to its problems.

Objective and Conduct of Aerial Reconnaissance

The primary objective of International Ice Patrol is to guard the southeastern, southern, and southwestern limits of ice in the vicinity of the Grand Banks so that shipping might be advised of the extent of that dangerous area. In addition, the Ice Patrol has the purpose of maintaining a detailed, up-to-date picture of the ice situation in the Grand Banks region.

An ice patrol flight is normally between 1,000 to 1,500 miles long (approximately 6 to 8 hours of flight time) and the track is carefully laid out so that a maximum area can be searched for the miles flown. Two or three experienced ice observers accompany each flight. To insure the intended search area is actually covered and for accurate iceberg positioning, precise piloting and navigation is demanded of the aircrew. Search altitudes are usually between 1,000 and 1,500 feet and every effort is made to stay beneath the overcast and provide the observers with maximum visibility. The desired altitude provides an excellent range of sight, while still enabling many individual surface features to be discerned. While flights are usually made in good or fair weather, the prevalence of fog in the spring and summer months occasionally requires that a flight be made in marginal or poor visibility where the aircraft must seek out its targets by radar and then descend to gain visual identification of either ship or berg.

The problem of identifying targets during marginal or poor visibility has plagued the Ice Patrol for many years. The usual 25 mile flight track spacing is a compromise between maximum area coverage and maximum probability of detection. To obtain 100 percent visual coverage, an observer must have 12.5 miles of visibility on each side. When this visibility is not obtained, which unfortunately is fairly frequent, reliance is shifted to radar. From the altitudes flown, smaller bergs can usually be picked up by radar at about 10 miles. These radar targets can then be identified by diverting from the planned track, unless ceiling and visibility prohibit. With ceilings frequently below 500 feet, inability to identify a radar target as an iceberg or a vessel becomes a serious handicap. An iceberg cannot be ascertained from a moving ship on the aircraft radar scope due to the speed of the aircraft which masks the greatly lesser surface vessel's motion. Small bergs and growlers are not normally detected by radar if the range exceeds 10 miles or if sea conditions are moderate to rough. When sea conditions are severe, larger bergs may also be missed.

Even if the area of responsibility was smaller and more aircraft were available for ice observing to enable complete coverage, weather would rarely cooperate. One of the most important portions of the area is the Tail of the Banks, an area of complex oceanographic conditions, where the cold water of the Labrador Current meets the warm water of the Gulf Stream. This area is frequently plagued by dense fog which normally renders ice observation by aircraft ineffective for weeks at a time during the crucial periods of April, May, and June when icebergs can normally be expected at the Tail of the Banks.

During light seasons when ice is restricted to the northern Grand Banks, or when only a small number of bergs are menacing the Tail of the Banks, guarding the ice limits and ice observation can be effectively accomplished by aircraft alone. During years when many icebergs survive to the Tail of the Banks, aircraft alone cannot properly do the job. The Ice Patrol surface vessel may then be required. Extended periods of poor flying weather may compound the heavy iceberg threat, or by itself necessitate a surface patrol vessel.

Only twice since 1959 has a surface patrol been initiated. The 1972 Season was the heaviest on record, with an estimated 1587 icebergs drifting south of 48°N, and the longest, 29 February to 4 September, a total of 189 days. The 1973 Season found an estimated 847 icebergs drift south of 48°N and equalled the 1972 Season in length, 24 January to 31 July.

The mission of the surface patrol is to provide an on the scene guard over the southernmost or more hazardous ice when trans-atlantic shipping is, or is about to be, menaced.

A surface vessel can search but a small portion of the area necessary to determine the ice limits. However, an aircraft on a day with good visibility will determine a large portion of the limits and observe the ice within these limits. Within a day or two after determination of the ice limits by aerial observation, ice conditions, and consequently ice limits, may have drastically changed. From the initial reported positions, Ice Patrol Headquarters will be drifting the icebergs using a computer drift model which considers wind and sea current conditions. Another effective ice observation flight may not be possible for days, during which time, the Ice Patrol vessel can search out the most dangerous areas and locate, observe, and guard the most dangerous icebergs, warning ships accordingly.

Thus, when large numbers of icebergs threaten and the aircraft and Ice Patrol vessel are both required, they complement each other in carrying out the mission of the International Ice Patrol. Since virtually all ice observation functions are accomplished now by aircraft, it is possible to confine surface patrols exclusively to known or suspected ice-inhabitated regions.

This combined air-surface procedure obviates the necessity for long and costly surface vessel searches that were characteristic of the years prior to 1946.

The Future

For the foreseeable future, aerial ice surveillance will remain the primary tool of Commander, International Ice Patrol, supplemented by a surface patrol when conditions warrant. The conduct of the flights will most likely remain as at present.

The advantages of aircraft over the surface vessel are impressive, namely increased area coverage in a greatly reduced amount of time. One disadvantage of aircraft replacing the surface vessel has been, as stated in the bulletin for the Season of 1964, a loss of continuous monitoring of specific icebergs that the cutters used to maintain. With aerial reconnaissance, an iceberg may be resighted only after a lapse of many days. Even then its identity may not be known with certainty. If iceberg dynamics are to be totally understood, surveillance of icebergs must be continuous. Weather often precludes this with aerial reconnaissance. Thus, there exists a pressing need for an all-weather remote sensor for Ice Patrol, capable of locating and enabling positive identification of targets.

By following this partial history of the Ice Patrol, it is apparent that the Ice Patrol is deeply engaged in research toward the goal of providing the best product available, at the lowest cost. To this end, Commander, International Ice Patrol is researching for the immediate future utilization of an operational all-weather system. Perhaps a package similar to the U.S. Coast Guard Airborne Oil Surveillance System (AOSS) or a present SLAR model will provide the all-weather detection capabilities desired.

When capable remote sensing systems are acquired, Ice Patrol will enter the third phase of its development: Phase I—Surface Patrol Vessel Scouting; Phase II—Aircraft Surveillance; and Phase III—Remote Sensing. This might well be in conjunction with a longer range model aircraft, which could facilitate operating from a base more remote from the Grand Banks region.

The final phase, as envisioned by the author, is Phase IV—Satellite. As the state of this art rapidly improves and becomes available, it should be possible in the near future to utilize either a geo-stationary satellite or one providing rapid repeat all-weather surface coverage of the area. This satellite would have the resolution to monitor individual icebergs and ice conditions and movement. On board sensors would measure the environmental conditions. The satellite would then broadcast the data to a receiving station for analysis prior to broadcast, or the satellite would develop the data itself and broadcast to shore transmission sites and direct to mariners. This latter method would be the most efficient and lowest cost to Ice Patrol.

To conclude, the International Ice Patrol renders an invaluable service to all mariners. Since the Patrol's inception, not a single ship has been sunk due to striking an iceberg outside the limits of all known ice as broadcast by the International Ice Patrol. Records show that ships have collided with bergs and sank inside these limits, indicating that the warnings were not heeded and ships steamed through the danger area. Outside the Patrol's area of responsibility several modern ships have hit bergs and sank. Most notable are the M/V HANS HEDTOFT on 30 January 1959, and the M/V BERGEMEISTER on 25 November 1965, both off Kap Farvel, Greenland. Thus, the unblemished record of Ice Patrol should not be allowed to lull anyone into a false sense of security, nor should this check Ice Patrol's improvement through scientific research.

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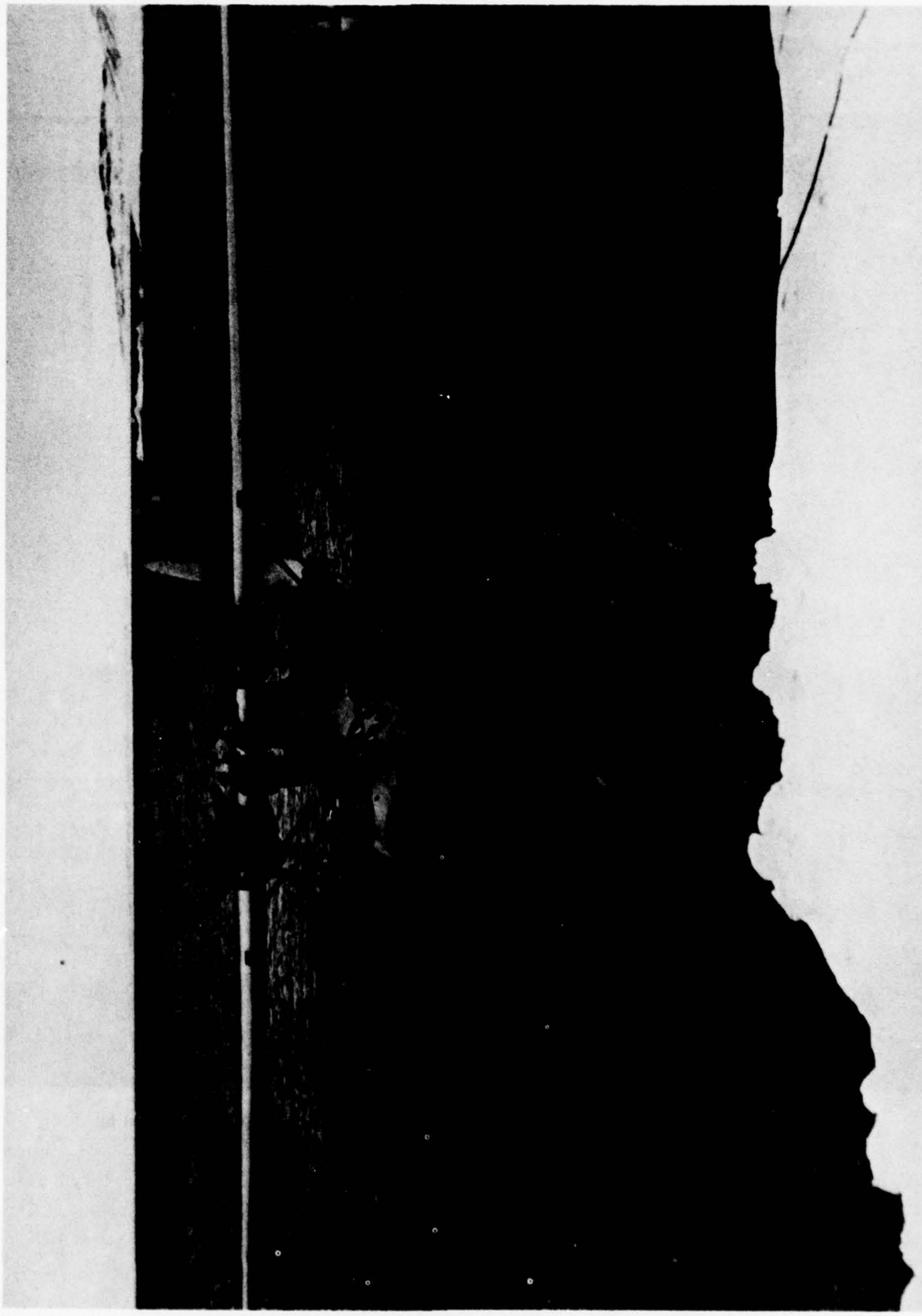

FIGURE A-1.—A Coast Guard PBY-5A Catalina. This aircraft was used on the first aerial reconnaissance flights conducted in support of the International Ice Patrol in 1946.

FIGURE A-2.—A Coast Guard HC-130-B aircraft. This type of aircraft has been used by Ice Patrol since the late 1950's.

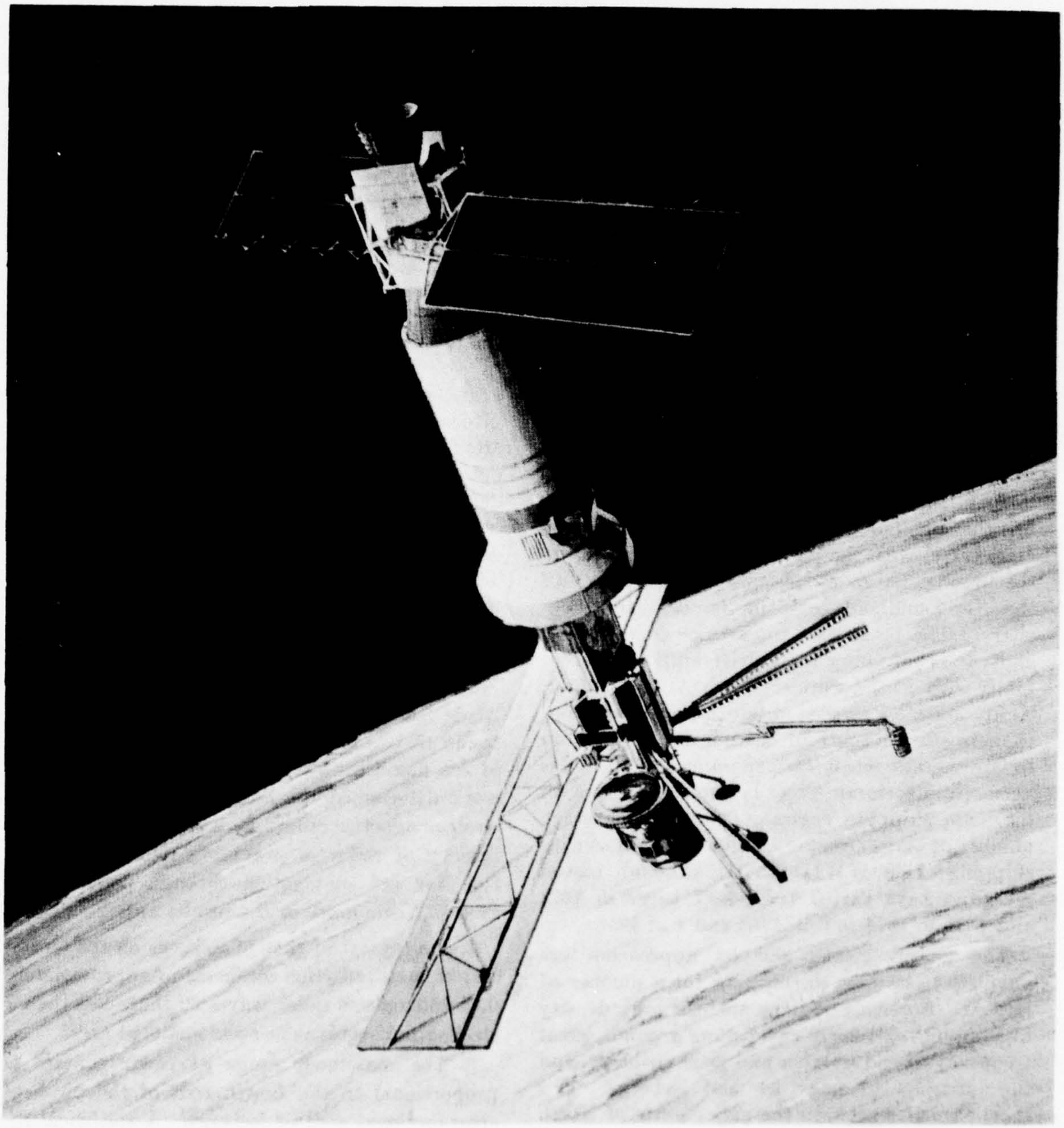

FIGURE A-3.—SEASAT-A due for launch in May 1978. This is planned as the first in a series of satellites designed to monitor the oceans. These satellites could prove invaluable to Ice Patrol, possibly eliminating the need for routine aircraft reconnaissance by the late 1980's.

APPENDIX B

REMOTE SENSING AS IT APPLIES TO THE INTERNATIONAL ICE PATROL

CDR A. D. Super, USCG

LTJG S. R. Osmer, USCG

Icebergs calve from the major glaciers of Greenland. As many as 10,000 are produced each year. Although exposed to open sea and warmer water in the summer and fall, these bergs become trapped in and protected by sea ice during the remainder of the year. Those that survive, travel with the pack ice from Baffin Bay to the western Labrador Sea and start to arrive off the Newfoundland coast in January and February. The bergs exit the sea ice to the south and east, continuing their drift until they eventually melt in the warmer North Atlantic water. As the pack ice recedes in late spring, bergs continue to survive south of latitude 48°N until mid to late summer when warmer water and open seas normally deteriorate them before they can reach the main shipping routes. The annual average number of bergs crossing latitude 48°N to menace shipping since WWII is 318, although season severities have varied from 1587 bergs in 1972 and 1387 in 1974 to 0 in 1966 and 1 in 1958.

The Grand Banks and its approaches are uniquely hazardous to shipping for a number of reasons. Foremost of these are: the high density of shipping, extremely rich fishing grounds, great frequency of bad weather and poor visibility, and the intrusion of pack ice and icebergs. The shortest routes between the major ports of North America and Europe pass through this area. The interchange of the coid, southward flowing Labrador Current with the warm North Atlantic extension of the Gulf Stream fosters both a nutrient rich fishing ground and a great profusion of fog. Additionally, North American storm tracks usually cross this area.

There are two possible approaches to make the area safer for shipping. They are: (1) elimination of the hazards and (2) location of the hazards with wide dissemination of location information so that they may be avoided. In attempts to destroy bergs, Ice Patrol has carried out a number of experiments including gunfire, demolition mines, high explosive bombs, thermite bombs, and carbon black without significant success. Destruction of the bergs is not feasible. Thus, Ice Patrol collects iceberg location information and disseminates warning information to shipping as widely as possible.

One might presume that, with modern surface radar, ships could detect and avoid icebergs. Aside from human errors of nondetection this is found to be untrue. In 1959 an extensive study of ice detection by radar was completed. This work determined the behavior of floating ice to electromagnetic radiation and assessed the efficiency of radar in providing reliable information for safe navigation through potential ice areas. A summary of the results are:

1. Ice typical of that in icebergs on the Grand Banks has a reflection coefficient of approximately 0.33 and reflects radar waves 60 times less than a steel ship of equivalent cross sectional area.

2. The maximum range of radar contact is proportional to the fourth root of the physical cross-sectional area of icebergs. A statistical relation derived from 152 observations shows that growlers (above water area of less than 1 x 6 meters) normally cannot be detected at ranges over 4 miles.

3. The Grand Banks and continguous areas of the North Atlantic exhibit conditions of subnormal radar propagation during the spring months when fog and ice hazards are most prevalent.

4. Waves over 1 meter in height might obscure a dangerous growler even with the expert use of anticlutter devices. If an ice target is not picked up beyond the sea return, it will not be detected at all.

5. Ice is not frequency sensitive. The response to S and X bands is the same. Furthermore, there is practically no difference in the response of sea water to S and X bands.

These results remain valid today. This past year, one merchant vessel collided with ice within the Ice Patrol broadcast limits of all known ice and incurred considerable damage and a small coastal freighter was lost with 6 lives following a collision with a berg in Hudson Strait. Often Coast Guard surface patrol vessels lose ice targets on radar while tracking them in close proximity.

Ice Patrol's early airborne remote sensing ventures consisted of aerial photography and conventional airborne radar. The reconnaissance aircraft usually flies standard tracks at an altitude of 1,500 feet in good weather over areas of probable icebergs. Radar data establish the actual position of berg sightings. With the prevailing low ceiling and minimum visibility, the reconnaissance aircraft attempts to descend just below the ceiling to a minimum of 400 to 500 feet. Diversions from assigned tracks are then made, when possible, to attempt visual identification of radar targets. The dangers inherent in this type of operation are obvious. Often the predominance of fog reduces reconnaissance effectiveness to zero. The problem encompasses not just target acquisition but that of classifying all detected targets as icebergs or nonbergs. The first attempt in this area was unsuccessful tests with a bolometer (forerunner of the airborne radiation thermometer) in 1954. Additional ART tests were conducted in 1964 when, although iceberg identification was not enhanced, basic current structure was deducted from the sea surface temperature on several occasions. An AN/ARR-33 passive microwave radiometer was flown from 1967 through 1969 with moderate success. Some targets were positively identified as bergs, although the fixed nadir window required overhead identification of all of the myriad of targets. A precision radiation thermometer (Barns PRT-5) maps sea surface temperature for use in iceberg melt determinations and approximation of major current features. In essence, these are the only operational tools today that supplement visual observations. Additionally, application of NOAA 4 high resolution infrared and visual imagery to obtain these data are being pursued.

As early as 1957, Ice Patrol conducted experiments with Side Looking Airborne Radar, because it was apparent that the high resolution would provide near all-weather detection and identification. This work, using an AN/APQ-55 (XA-1) K-band real aperture system, was limited to scope due to poor electronic reliability but provided great hope for future systems. In 1969 Ice Patrol commenced experiments with a modified AN/DPD-2 Ku-band, real aperture SLAR system to evaluate its capabilities. From data obtained on regular patrol flights in 1970 and 1971, the Coast Guard Research and Development Center formulated a system of target discrimination between icebergs and other objects through interpretation and classification using analysis of basic clues. Seven clues consisting of size, shape, shadow, tone, texture pattern, edge and wake were considered. A photographic interpreter would analyze each target for convergence of evidence in a "logical search" phase. This system proved quite satisfactory and reasonably reliable for post mission research analysis but was operationally constrained by the requirements to develop film (a vacuum in flight developer was not available), the extensive amount of imagery to be viewed, and the near-laboratory conditions required for handling enlarged imagery which were not available in the field. The AN/DPD-2 SLAR was again flown during the 1972 and 1973 seasons, but its use was terminated due to continuing maintenance probl ms with this aged system and the imagery handling problem.

As a follow on to previous work in support of the Great Lakes Navigation Season Extension Demonstration Program during the winter of 1975, NASA Lewis Research Center installed an AN/APS-94C modified SLAR system in a Coast Guard HC-130B aircraft. At the conclusion of Great Lakes season, this system, with additional modifications and the Moving Target Indicator mode installed, was flown experimentally in support of the International Ice Patrol. An Edo-Western dry film processor was installed in the aircraft and data transmission modes were not utilized. Twelve missions were flown with the

SLAR aircraft at desired altitude while the regular reconnaissance aircraft provided surface verification flying routine search tracks and investigating all SLAR targets. Missions were flown over the open water iceberg areas of the Grand Banks and into the pack ice area upstream along the Labrador coast. Various adjustments to the system were made with a wealth of good data. Results were basically as expected. The systems provided greatly increased coverage and effectiveness, obtained all targets including whales and debris, easily detected icebergs in sea ice and penetrated all weather except heavy rain. Small bergs were consistently detected to 48 kilometers with a signal to noise ratio of at least 2. The basic problem continued to be target identification. Other problems were: slow target geographical location by manual plotting, sea return interference, and antenna fade. The Moving Target Indicator mode provided unsatisfactory results mostly due to equipment performance and slow target movements in azimuth. The Ice Patrol and NASA Lewis plan to continue experimental SLAR flights during the 1976 ice season attempting to solve the target discrimination and data handling problems. Additional modifications will include: a moving window display with automatic target designation, several approaches to automatic target recognition and identification, better amplitude-time discrimination, and depolarization of echoes.

The future looks promising. The Coast Guard prototype Airborne Oil Surveillance System (AOSS) has been flight evaluated and will soon be installed in a service C-130 aircraft. This system includes an AN/APS-94D SLAR, a 37-GHz passive microwave imager, a multispectral line scanner and a low light television system with position reference and real-time processor/display console. AOSS was originally developed for marine pollution detection and cleanup support, but will be used in other Coast Guard mission areas, particularly the International Ice Patrol. A multisensor system with separate detection and interrogation functions is another approach to be evaluated. Other advances with good potential of target identification are the use of synthetic aperture systems and a dual mode operation with low resolution, broad swath search and narrow width, high resolution scrutiny. But these are presently beyond Ice Patrol's limited funding scheme. Ice Patrol is also well represented on the SEASAT user working group and, in the long-term, envisions such a satellite to continuously monitor the area of responsibility, not only detecting sea ice and icebergs, but also providing needed surface environmental data.

But that is in the future. Today Ice Patrol is still plagued by its old nemesis, fog, while continuing to gua[illegible] the Grand Banks against another TITANIC disaster.

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APPENDIX C

"SEARCH" COMPUTER PROGRAM DESCRIPTION

By R. Q. Robe

U.S. Coast Guard Research and Development Center

"SEARCH" is a computerized data storage and retrieval system adapted to International Ice Patrol (IIP) dynamic height data requirements. All historical dynamic height data are indexed by 20 minute latitude and longitude intervals, month, and year. "SEARCH" permits monthly and yearly comparisons to be made between dynamic heights on file. The method used is to calculate the sum of the squares of the differences in dynamic height for corresponding locations between the month and year of interest and all other month and year data sets on file. Squaring the difference eliminates negative values prior to summing. The sum of the squares of the difference in dynamic heights between the reference month and a historical month is calculated only for the area of common geographical coverage. When all sums of squares of differences in dynamic height have been calculated, they are ranked from least sum upward. The sum of the squares value should be treated as an ordering index only and does not have any physical significance. "SEARCH" also supplies the number of dynamic height data points in each of the sets (month and year) used in the comparison and the number from each set that coincide with those of the reference set.

The "SEARCH" program output is designed as an aid to IIP oceanographers in making better use of the dynamic height data collected each season by the IIP oceanographic vessel. It is based on the assumption that history repeats itself to the extent that over a large number of years the current systems in the IIP area of interest will show characteristics which are similar to other seasons. The months and years picked for use from the ordered list by the oceanographer should have a low sum of squares and a high percentage of data locations in common with the reference month.

An example will be instructive. Input 96 dynamic height data points from May 1975 as the reference month. Comparisons are made with data file and the following output is produced. The oceanographer would then scan the output and take a closer look at those months which have a low sum of squares (the output ranks only the top 25 possibilities) and also a high number of data point locations in common with the reference month. Probably the best months to look at would be April 1959, May 1959, June 1959, May 1952, April 1939, and May 1958. The dynamic height charts for these months can be examined for the best qualitative fit with the reference month. From this point, those months which compare well can be used to qualitatively extend the boundaries of the survey area and aid in matching the contours of dynamic heights of the reference data to those on the IIP normal charts (which are included in the data file along with the historical data). In this example, May 1975 compared well with April, May, and June 1959. Thus it is likely that the current system in 1975 would be very similar to that in 1959. Given the same availability of icebergs in both years, similar drift patterns can be expected.

SEASONS THAT BEST COMPARE WITH MAY 1975

NR	*Closest Match*		*NR OBS*	*Least Square*	*Matched Points*	*Percent*
1	April	1959	237	721	96/96	100.0
2	May	1959	238	2685	88/96	91.7
3	April	1954	248	3348	50/96	52.1
4	April	1965	76	4784	35/96	36.5
5	May	1969	62	5028	3/96	3.1
6	April	1948	39	5701	19/96	19.8
7	May	1968	112	6196	40/96	41.7
8	April	1970	206	6551	29/96	30.2
9	June	1959	400	6614	92/96	95.8
10	June	1934	175	6717	20/96	20.8
11	June	1964	206	7401	68/96	70.8
12	June	1950	167	8481	66/96	68.8
13	April	1968	130	8575	59/96	61.5
14	May	1939	85	8667	70/96	72.9
15	May	1948	61	10228	51/96	53.1
16	April	1972	118	10614	25/96	26.0
17	April	1966	25	10727	4/96	4.2
18	May	1952	270	11165	82/96	85.4
19	June	1954	462	11361	80/96	83.3
20	June	1939	175	11524	81/96	84.4
21	June	1972	52	11530	13/96	13.5
22	April	1967	51	11587	9/96	9.4
23	April	1939	196	11779	92/96	95.8
24	June	1968	127	12079	61/96	63.5
25	May	1958	409	12577	92/96	95.8

In summary, this is a qualitative, not a quantitative tool. It is not designed to give definitive answers to the current velocity prediction problem, but rather to aid the IIP oceanographer to a better understanding as to how the ice season is developing and how to combine the present data, which cover a limited area, with the IIP normal dynamic height charts, which cover a large area.

APPENDIX D

PHYSICAL PROPERTIES OF ICEBERGS
TOTAL MASS DETERMINATION

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and

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Analysis of stereo pairs of twenty-two icebergs, in the region of Davis Straits, reveals that a reasonable estimate of total iceberg mass, in metric tons, can be arrived at by multiplying the gross dimensions of the iceberg (height x width x length) together and the multiplying this product by a factor of 3.01. This factor accounts for the density difference between seawater and fresh water ice; it also accounts for the average shape and mass distribution of icebergs.

Introduction

Before a model for the deterioration of icebergs can be constructed and verified, it is necessary that actual observations be made of icebergs melting and calving. A prerequisite for deterioration observations is a simple technique for the determination of iceberg mass. KOLLMEYER (1966) determined the mass of icebergs by constructing a contour map of the berg using horizontal photographs taken at intervals of every 30° of arc around the berg. This technique was very laborious, not very accurate, and could not be used to cover many bergs. We felt that a more practical approach was to use aerial photography and construct a topographic type map of the bergs from stereo pairs. Since we lacked any vertical control points, such as exist on land, horizontal and oblique photographs were taken to provide a measure of vertical scale.

In order to obtain the necessary photography the CGC EDISTO was used for a platform for two HH52 helicopters. The EDISTO was assigned to this project from approximately 16 July 1974 until 4 August 1974. The first icebergs photographed were just north of Goosebay, Labrador. From there the EDISTO proceeded north, until just north of the Arctic Circle, working icebergs as we went. From the Davis Straits area just north of the Arctic Circle we proceed south and then east in order to pick up icebergs off the west coast of Greenland.

Data Collection

Thirty-two icebergs were photographed. Of these, twenty-one were of high enough quality to determine the above water volume. Hydrographic stations taken near each iceberg measured the average density of the seawater in the area.

Aerial photography was acquired from USCG HH52 helicopters, using 500 EL Hasselblad 70 mm format cameras with 100 mm f3.5 lenses. These cameras were installed in a lightweight aerodynamic camera mount designed at the CG R&D Center. The mount is a lightweight (85 pounds with four cameras) multi-purpose unit which requires no airframe modification for installation. Design limits are air speeds 140 knots or less and unpressurized flight altitudes. The practical limiting altitude is 6,000 feet. The mount is designed to fit all Coast Guard aircraft capable of meeting these limits.

Parallax measurements used in determining heights of points on the iceberg were made on stereographic photographs with the model 121 GE stereo comparagraph. Sea level cross-sectional area was measured with the B&L photo data quantitizer.

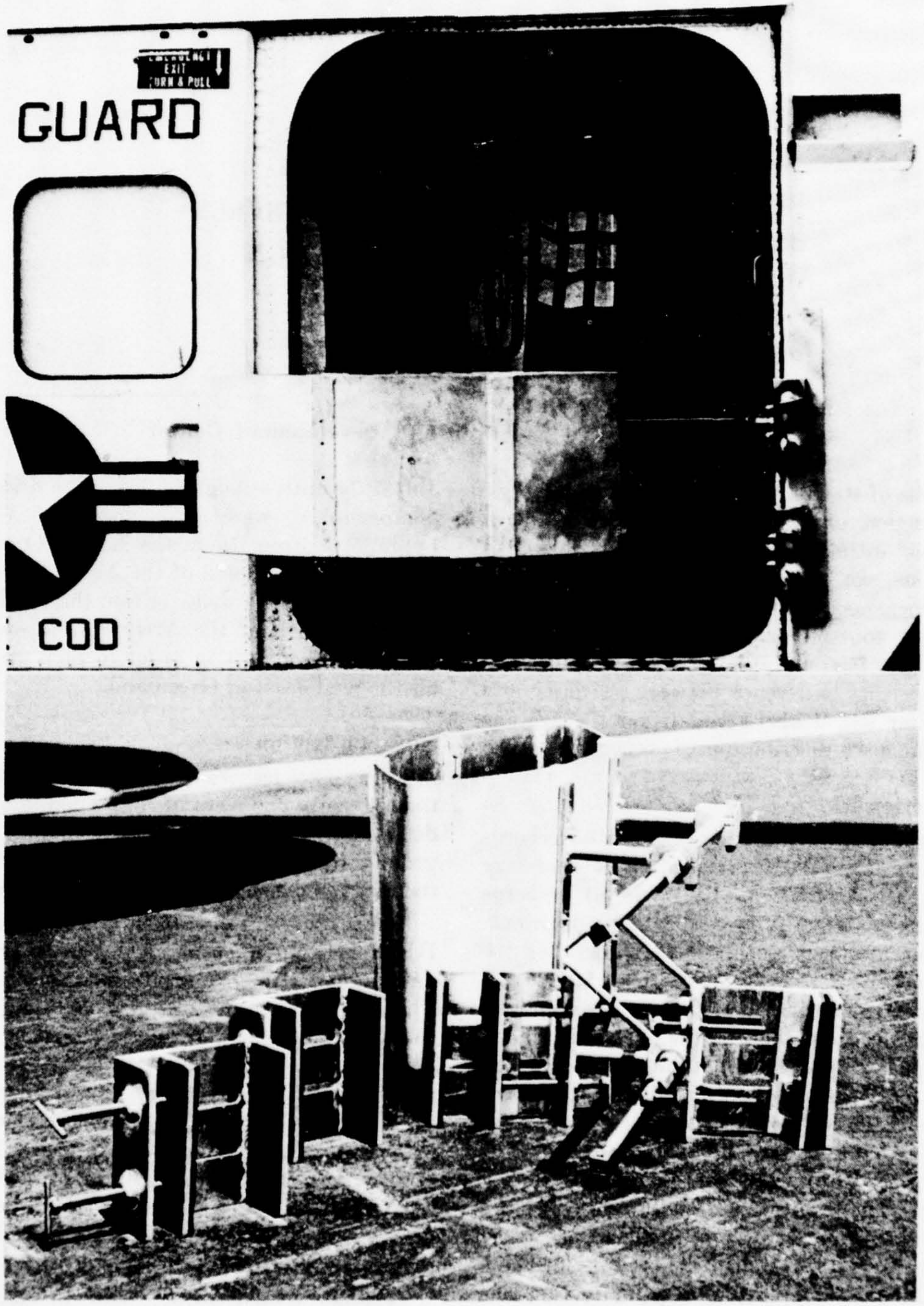

FIGURE D-1.—Multi-purpose, portable camera mount

To accurately determine the total mass of an iceberg, the above water volume and mass must first be determined. This involved three types of photographs; horizontal, oblique and vertical. In all cases the 500 EL/M 70mm cameras were used. Black and white negative film was used, with all analysis done from positive prints.

Horizontal and oblique photography was obtained by using a leveled tripod from inside the helicopter. Slow, level passes at selected altitudes and offset distances were made at four locations around the iceberg. These were usually 90 degrees apart. Both horizontal and oblique photographs were obtained at each station. Vertical photography was obtained using the previously described camera mount. Adequate overlap was obtained by taking repetitive frames at predetermined time intervals. Utilization of each type of photography is explained in the pilot study and analysis sections which follow.

Pilot Study

After several attempts to contour the iceberg in a manner similar to a topographic map, we came to the conclusion that such a straightforward method was impossible due to the extreme surface gradients found on a typical iceberg. A new approach was then tried which proved successful. A grid of randomly selected points was used to locate the position of the parallax measurements. Since no point on the berg was more likely to be sampled than any other, it was possible by sampling a sufficient number of randomly selected points to determine the average height of the iceberg to any desired accuracy. An accuracy of better than ± 2 meters was chosen and a pilot study was conducted to determine the sampling density required. It was determined that a sampling density of .02 points per square meter would give a mean height that had a standard error of less than two meters.

A grid of .02 random points per square meter at an average scale of 1:2000 was used. The variations in actual size of the icebergs resulted in variations of photographic scale. In all but a few cases, the number of random sample points exceeded the minimum density.

Change in Height Versus Change in Parallax

The stereo pairs used had no real reference level, since the sea surface had no detail in the photographs. Therefore, it was necessary to construct a linear relationship between the change in height (Δh) and the change in parallax (Δp) for each iceberg. To construct such a graph, points on the iceberg were chosen on the horizontal and oblique photographs and the actual heights of these points were computed. These same points were then located on the stereo pair and the parallax was measured. Using a least square fit to these points (four to eight for each iceberg), a ratio of Δh to Δp was established for each iceberg. This ratio was used to convert the iceberg's mean parallax ($\overline{\Delta p}$) to mean height ($\overline{\Delta h}$). By comparisons with actual height measurements we determined that the heights from the oblique photographs were more reliable than those from the horizontal photographs. This was because the only scale reference for the horizontal photography was the presence of the helicopter in the field of vision. Depth of field, orientation of the helicopter (e.g., level or not) and its position in relation to the plane of the icebergs were not constant or definable. The oblique mensurations on the other hand did not require a scale reference.

Therefore, we used only the oblique photography to determine the ratio of $\overline{\Delta h}$ to $\overline{\Delta p}$.

Oblique Mensurations

The principal point (P) is the center of the photographic format. A line drawn through (P) perpendicular to the visible horizon is the principal line (PH_1), the point of intersection being (H_1). The depression angle (θ_1) between the optical axis of the camera and the visible horizon is calculated:

$$\tan \theta_1 = PH_1/(f \cdot M)$$

where (f) is the focal length of the camera in milimeters and (M) is the enlargement factor of the photograph. The dip angle (D) between the visible horizon and the lens horizon is computed.

$$D = 9.03\sqrt{H}$$

where (H) is the flying height of the helicopter in meters. The depression angle (θ) between the optical axis of the camera and the lens horizon is found by $\theta = \theta_1 + D$. The distance (PH) measured along the principal line to the lens horizon is calculated:

$$PH = f \cdot \mathrm{Tan}\ \theta \cdot M$$

This distance is laid out along the principal line through point H_1 in the direction of the visible horizon. The lens horizon is then drawn perpendicular to the principal line through point (H). Heights, in meters, of selected points on the iceberg can be determined in relation to the lens horizon by using the following formula:

$$h = \frac{(K)(H)(a-b)}{a(K-b)}$$

where; (K) is a constant equal to:

$f/(\sin\theta \cdot \cos\theta)$

H = Flying height in meters.

a = Perpendicular distance from lens horizon to the water line, measured in millimeters.

b = Perpendicular distance from lens horizon to the top of selected points, measured in millimeters.

All angles are in degrees, and all photographic measurements are in millimeters.

Analysis

A stereo pair for each iceberg was set up with a random sampling grid. The parallax was measured to each point on the grid. The mean parallax for the iceberg was then determined using a simple average. This mean parallax (P) was converted to mean above water height (h) for the iceberg by using the ratio of h to p for each iceberg. The mean height multiplied by the sea level cross-sectional area of the iceberg, as determined on the a photo data quantitizer, then equalled the above water volume of the iceberg. The iceberg has a mean density of 0.8997 metric tons per cubic meter (Smith, 1931) and sea water in the area of study had a density between 1.024 and 1.027 g/cm^3. The total volume, V, of the iceberg is given by

$$V = V_1 + V_2$$

where V_1 is the above water volume and V_2 is the below water volume. The mass, M, of the iceberg is then given by its total displacement

$$M = \rho_{sw} V_2$$

where ρ_{sw} is the density of sea water. The mass of the iceberg is also given by the expression

$$M = \rho_i V = \rho_i (V_1 + V_2)$$

where ρ_i is the density of glacial ice. Equating (2) and (3) gives

$$\rho_{sw} = \rho_i (V_1 + V_2)$$

solving for V_2 in terms of V, and using $\rho_i = .8997$ $^{gm}/_{cm^3}$ and $\rho_{sw} = 1.0255$ $^{gm}/_{cm^3}$ yields a result

$$V_2 = 7.15\ V_1$$

$$V = 8.15\ V_1$$

from (1) to (5). From equations (3) and (6), assuming a uniform density for the iceberg, the total mass metric tons of an iceberg is then 7.33 times the above water volume of the iceberg in cubic meters.

$$M = 7.33\ V_1$$

A least square analysis of V_1 as related to product of the longest side (L), shortest side (W), and the height of the highest point (H), indicates that

$$V_1 = .41\ LWH$$

combining (7) and (8) yields

$$M = 3.01\ LWH$$

The errors which contribute to the total error of iceberg mass measurements originate in the following ways.

a. The measurement of the heights of selected point on the berg has an error estimated at ±5%.

b. The parallax measurements using the stereocomparagraph have an error of ±2%.

c. Calculations of the mean berg height from heights taken at random points have an error of less than ±9% associated with it.

d. The waterline cross-sectional area can be measured by the optical image analyzer to within ±1%.

Combining the errors using a simple summation yields a total error of ±17% or less.

Results and Conclusions

The purpose of this study was to develop a technique for easily and quickly estimating the mass of an iceberg. Several relationships were tried such as separating bergs into visual shape classes, plotting height against berg mass, and using a combination of these two approaches. The correlation that appears to be most satisfactory both from the point of view of simplicity and also accuracy is the correlation between the product of the longest side, shortest side, and height of the highest point with the total mass of the iceberg. This approximates the above water portion of the berg with a rectangular box. If the length, width and height are measured in meters, then the total mass of the berg in metric tons is estimated to be 3.01 times the product.

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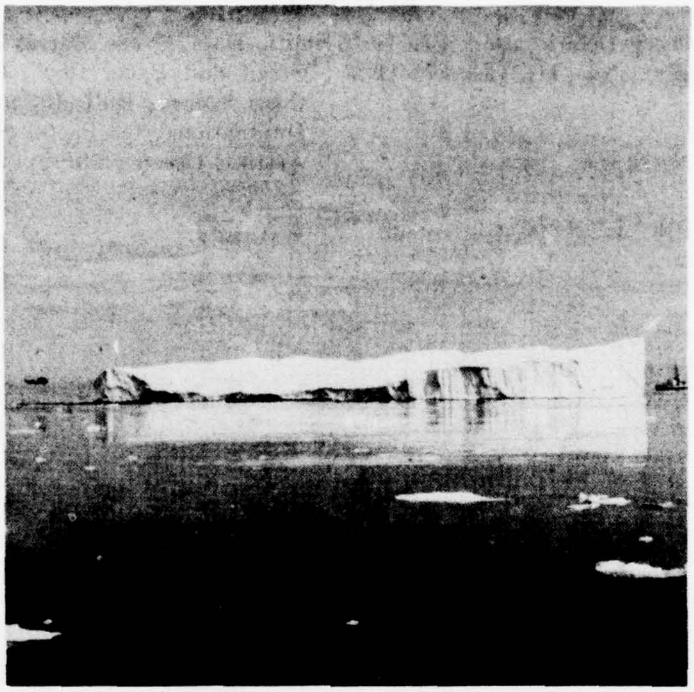


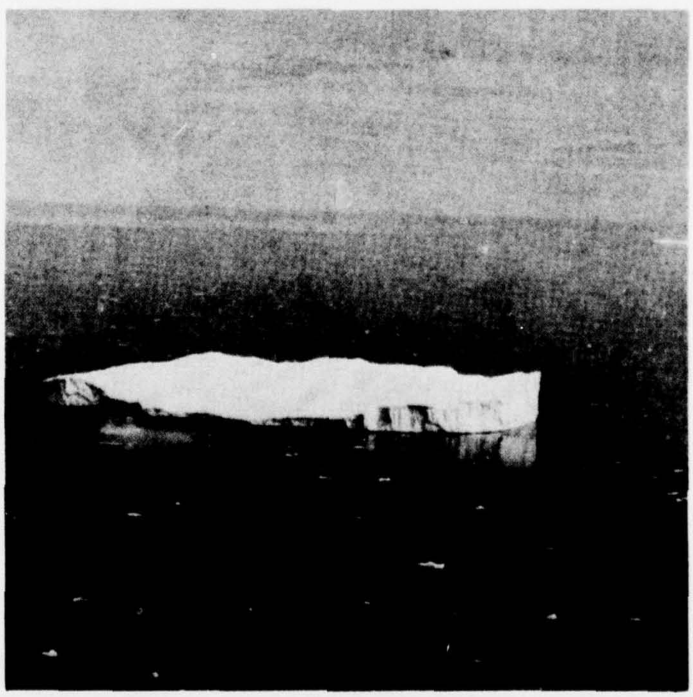
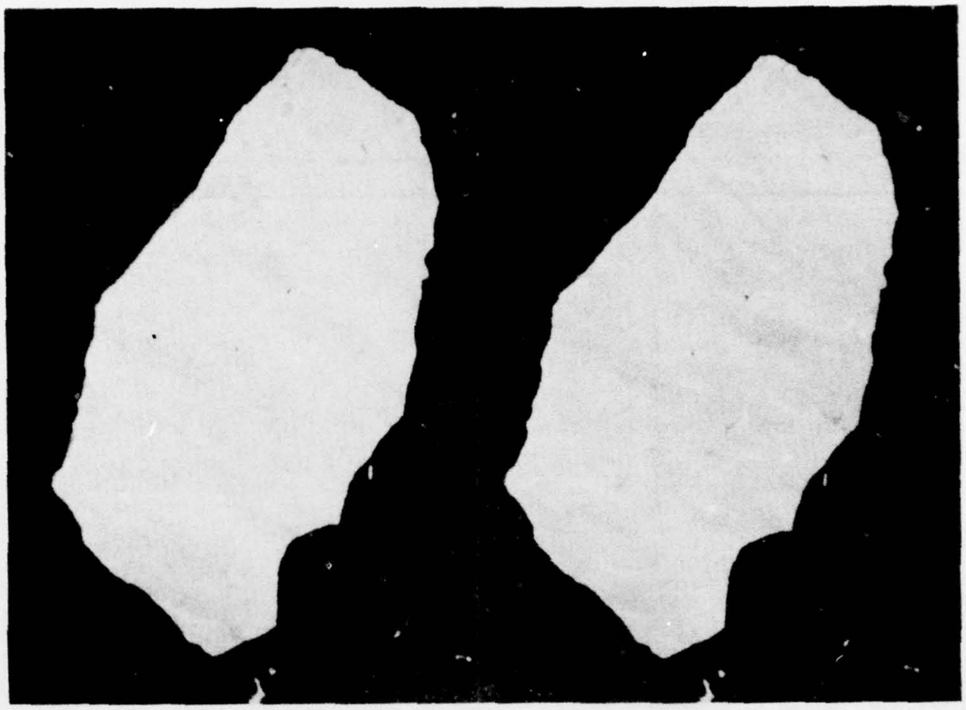


Figure D-2.—Horizontal (A) and Oblique (B) photographs of an iceberg



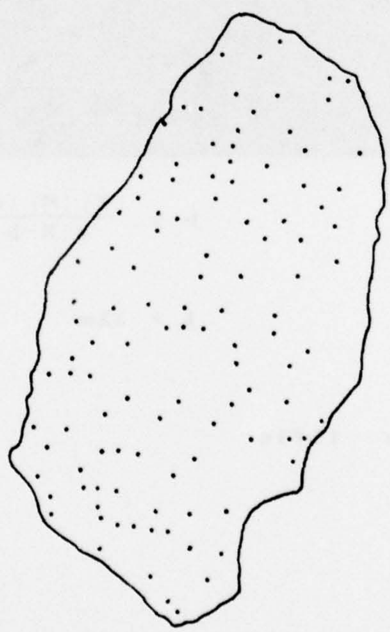
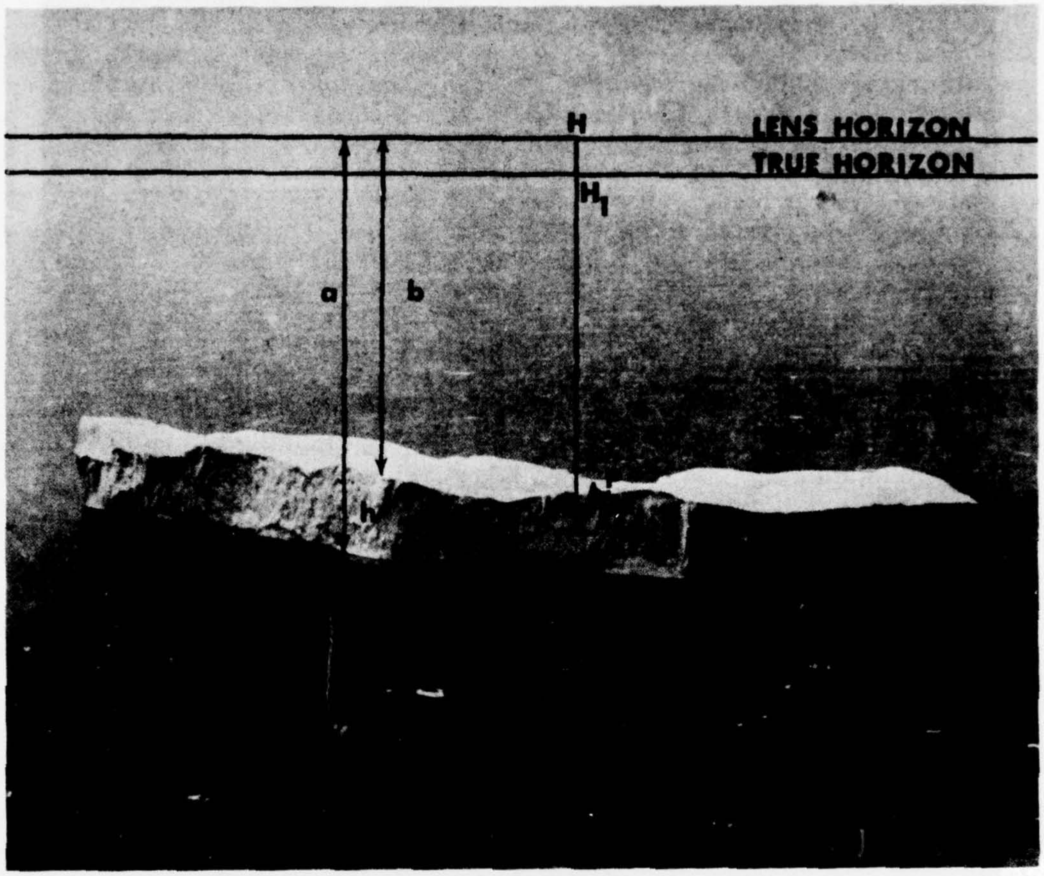


FIGURE D-3.—Examples of stereo pair (top) and random sample point (bottom)



$H = 152m$

$PH_1 = 55mm$

$f = 100mm$

$M = 3.5X$

$\tan \theta_1 = PH_1/(f \cdot M) = .15714$

$\theta_1 = 8.93°$

$D = 0.03\sqrt{H} = .37°$

$\theta = 9.30°$

$PH = f \cdot \tan\theta \cdot M = 57mm$

$K = f/(\sin\theta \cdot \cos\theta) = 627$

$$h = \frac{(K)(H)(a-b)}{a(K-b)}$$

$h = 32m$

FIGURE D-4.—Oblique Mensurations

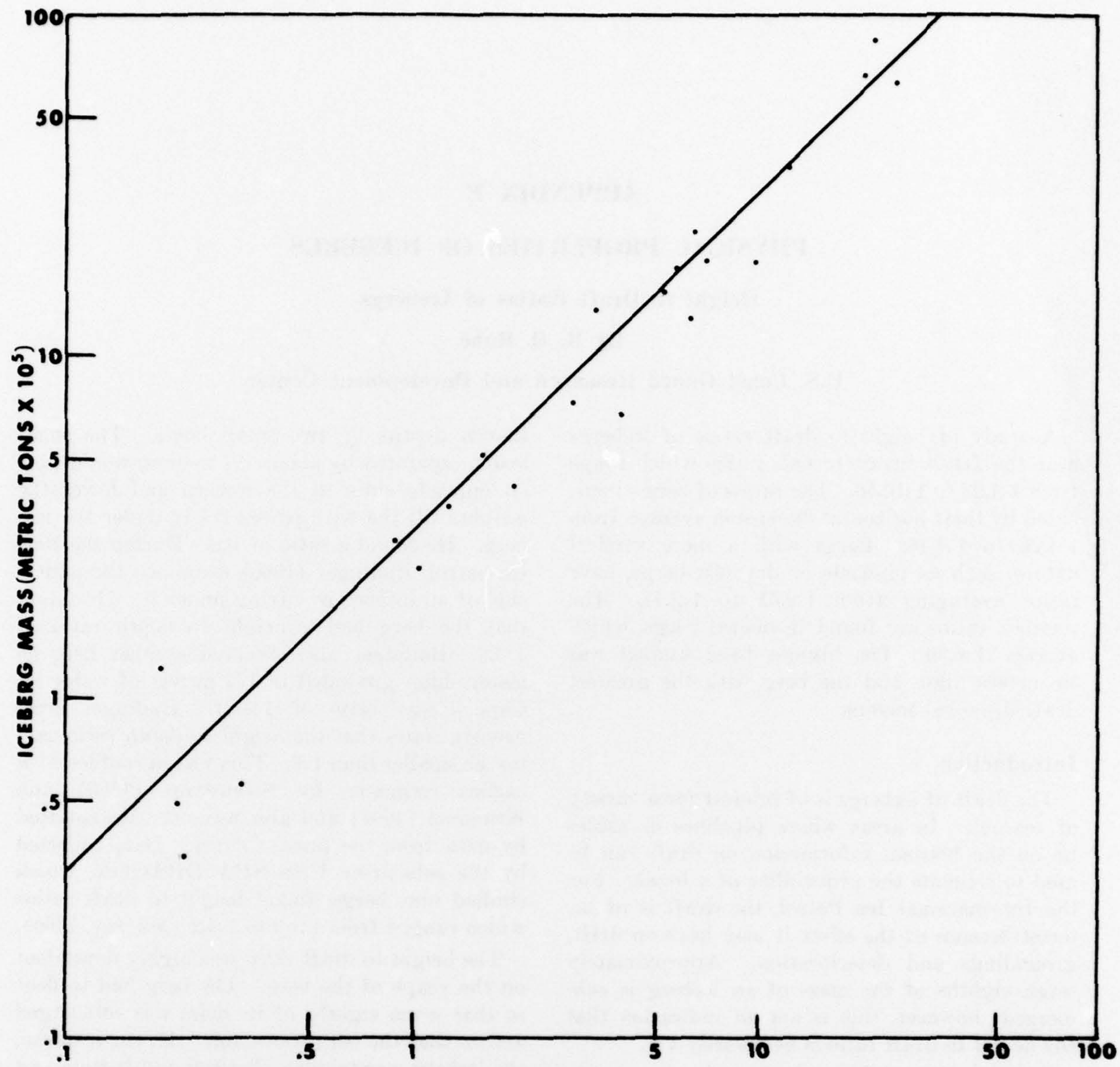


FIGURE D–5.—Least square fit of the above water volume approximation (height of highest point X long horizontal axis X narrow horizontal axis) versus the total calculated iceberg mass.

APPENDIX E

PHYSICAL PROPERTIES OF ICEBERGS

Height to Draft Ratios of Icebergs

By R. Q. Robe

U.S. Coast Guard Research and Development Center

A study of height to draft ratios of icebergs near the Davis Strait reveals ratios which range from 1:1.28 to 1:10.56. The ratios of bergs dominated by their horizontal dimension average from 1:4.26 to 1:4.46. Bergs with a more vertical nature, such as pinnacle or drydock bergs, have ratios averaging from 1:2.31 to 1:2.41. The smallest ratios are found in domed bergs, which average 1:6.30. The highest berg studied was 59 meters high, and the berg with the greatest draft drew 161 meters.

Introduction

The draft of icebergs is of interest for a variety of reasons. In areas where pipelines or cables lie on the bottom, information on draft can be used to estimate the probability of a break. For the International Ice Patrol, the draft is of interest because of the effect it may have on drift, groundings and deterioration. Approximately seven eighths of the mass of an iceberg is submerged; however, this is not an indication that the height to draft ratio is necessarily 1:7.

Estimates of height to draft ratios were made as far back as the late 19th century. Steenstrup (1893) gives the ratio as 1:7.4 and 1:8.2; while Krummel (1907) gives a ratio between the extremes of 1:18 and 1:4, with most falling in the range of 1:5 and 1:6. Grounded icebergs were used to obtain the earliest estimates of the ratio. Dawson (1907) found a berg stranded in the Strait of Belle Isle in 1894 which had a ratio of 1:3. Again in the Strait of Belle Isle, Rodman (1890) found a 30-meter pinnacle berg grounded in 29 meters of water for a ratio of nearly 1:1. To estimate draft, Smith (1925) used a drag wire strung between two heavy weights and towed at known depths by two small boats. The small boats, separated by about 137 meters, would pass on opposite sides of the iceberg and lower the weights till the wire passes freely under the iceberg. He found a ratio of 1:2. During the 1959 ice patrol, Budinger (1960) examined the underside of an iceberg by diving under it. He found that the berg had a height to depth ratio of 1:3.3. Budinger also observed another berg 55 meters high grounded in 175 meters of water off Cape Race (ratio of 1:3.2). Budinger erroneously states that the height to depth ratio cannot be smaller than 1:6. This was in conflict with earlier estimates by Steenstrup (1890) and Krummel (1907) and also was not substantiated by data from the present study. Data collected by the submarine USS SEA DRAGON, which studied nine bergs, found height to draft ratios which ranged from 1:1.3 to 1:4.2 (Murray, 1960).

The height to draft ratio was highly dependent on the shape of the berg. The berg had to float so that seven eighths of its mass was submerged and so that the berg was stable. If, for instance, the iceberg was tabular (flat top and bottom and vertical side) a ratio of 1:7 would be expected. If the above-water portion was rounded and smooth, while the underwater part was pointed, then a ratio smaller than 1:7 could be expected, even as small as 1:9 or 1:10. The other extreme was the case where the underside of the berg was rounded and smooth and the above-water portion had towering vertical walls. The most pronounced case of this type was the drydock berg where an embayment had been cut out of the center of the berg leaving only a thin rim of great height and little mass. These could have a height to draft ratio which approached 1:1.

The purpose of this study was to see if the above water shape of icebergs was related in a significant way to the height to draft ratios for those bergs. Height to draft ratios were obtained for a total of 30 icebergs.

Methods

Measurements of iceberg draft were taken with a Kelvin-Hughes Transit Sonar during a cruise aboard the CGC EDISTO, July 1974. The EDISTO was operating in the Davis Straits area and along the west coast of Greenland. The Kelvin-Hughes Transit Sonar was designed to conduct bottom surveys; however, we were interested in vertical targets rather than in horizontal ones. The sonar transducer produced a beam .5° wide in the horizontal and 52° wide in the vertical, both being to the 3db level. For our purposes the transducer was pointed down by 26°, so that the top of the fan-shaped beam would just pass under the surface of the water and the bottom of the beam would be depressed at 52°. The transit sonar was designed for use from a small boat with only a few feet of freeboard. It was mounted on the EDISTO's arctic survey boat (ASB). This arrangement worked well, providing cover for the deck gear and personnel, along with high maneuverability and good speed control. The first five bergs were surveyed from the ASB with great success. Use of the ASB was then discontinued because the single point bridle used to raise and lower it was hazardous in any but the calmest weather. For the next two bergs the motor surf boat (MSB) was used. It was inadequate because the equipment was exposed to the weather and because the boat had such little stability that it was difficult to maintain the transducer orientation with respect to the iceberg. The MSB was retired due to a failure of the boat davit.

Finally, a method for using the transducer from the EDISTO itself was devised. The freeboard of the EDISTO was approximately eighteen feet from the rail to the water line aft of midship. A 21 foot pipe was fabricated that would support the transducer three feet below the water line. The transducer was mounted on the bottom of the pipe, and the pipe was manhandled from the deck to the outboard position for each run. Small chunks of ice were a constant problem and once sheared the transducer off the supporting pipe. A safety line attached to the transducer prevented loss of equipment. With the sonar on the EDISTO it was possible to have the deck gear in the oceanographic laboratory and also to operate from a very stable platform.

When the ship was positioned near enough to the berg, the beam of the sonar was completely intercepted by the iceberg. As the ship circled the berg, it increased the distance from the berg so that at some part of the sonar beam passed under the berg. The distance was increased till the ship was at maximum range (550 meters slant distance from the bottom of the berg) or a good echo was no longer received.

Five assumptions were made in interpreting the record. First, that the first echo was returned from the near surface portion of the berg; second, that the strong echos were reflected from vertical surfaces on the underwater portion of the berg; third, that weak returns came from walls which slope away from the observer along a radial of the sonar beam; fourth, that blank areas in the return were the results of shadow areas caused by caves, holes or ridges in the iceberg; and fifth, that if the transducer was far enough away from the berg the last return from the berg comes from the deepest portion of the berg.

The entire record of the iceberg sonar trace was examined and points which were representative of the deepest point on the berg were chosen. These points were plotted on radial grid so that the radial distances to the various portions of the berg could be converted to vertical measurements of berg draft. These estimates of draft were plotted versus distance to the berg. As the distance to the berg increased, the draft estimates approached an asymptote which was assumed to represent the true draft of the iceberg.

Discussion

The subaerial shapes of icebergs are extremely varied, sometimes displaying fantastic forms. Some bergs have "windows" in high vertical walls, while others are pockmarked like a piece of Swiss cheese, and still others have huge grottos or voids. As a means of organizing the shapes of the visible portion of icebergs into some system certain prominent characteristics have been chosen and used for typing icebergs into classes. These classes are based solely on visual identification.

This study examines whether or not the visual classification of icebergs is a meaningful way to classify the height to draft ratios of these bergs. Based loosely on Murray (1968), the icebergs of this study were separated into five general categories based on gross visual shape characteristics.

1. Tabular bergs were horizontal, flat-topped bergs with a length to height ratio generally greater than 5:1.

2. Broken tabular bergs were those that were mainly horizontal but whose surface was highly fractured, with a length to height ratio generally greater than 5:1.

3. Pinnacled bergs had a large central spire or a pyramid of one or more spires dominating the shape.

4. Domed bergs had a large, smooth rounded top which had once been submerged.

5. Drydocked bergs had an eroded U-shaped slot cut by wave action surrounded by high vertical walls or pinnacled.

The mean height to draft ratio for each of the five visual classes was computed and compared statistically to the mean ratio for all other classes. The null hypothesis is that there is no significant difference between the height to draft ratios for the visual classes of icebergs.

The height to draft ratios for the icebergs studied ranged from 1:1.28 to 1:10.56 (Tables 1 through 5). The 1:1.28 value was in line with previous measurements, but the 1:10.56 value was smaller than any of the previously reported ratios. The 1:10.56 ratio was associated with a domed berg where the rounded above-the-water portion had the maximum mass in the minimum height. To attain this value the underwater portion probably had a taproot-like formation.

The tabular and broken tabular (Tables 1 and 2) had almost identical characteristics. These were the most massive of the bergs, having lengths which were observed to reach 600 meters in this study and much larger in other studies. The mean heights for the tabular and broken tabular were 28.3 and 27.7 meters respectively; the mean drafts being 108.0 and 107.1 meters respectively. Of course, the height to draft ratios were quite similar also, being 1:4.46 for the tabular and 1:4.26 for the broken tabular. It appears that generally all bergs which were dominated by a horizontal dimension can be grouped together in respect to their draft ratios.

Table 1. Height to draft ratios for tabular bergs

	Height (meters)	*Depth (meters)*	*Ratio (1:)*
	35	122	3.48
	40	80	2.00
	30	137	4.57
	21	97	4.62
	32	84	2.62
	12	115	9.58
	28	121	4.32
Mean	28.3	108.0	4.46
S.D.	9.3	21.4	2.47

Table 2. Height to draft ratios for broken tabular bergs

	Height (meters)	*Depth (meters)*	*Ratio (1:)*
	41	139	3.39
	18	60	3.33
	13	94	7.23
	30	111	3.70
	55	161	2.93
	21	88	4.19
	20	126	6.30
	21	78	3.71
	30	107	3.57
Mean	27.7	107.1	4.26
S.D.	13.2	31.4	1.48

Pinnacle bergs (Table 3) and drydock bergs (Table 4) also appear to have been quite similar to each other. These bergs had great height with comparatively little mass. The average height to depth ratios for pinnacle bergs was 1:2.31 compared to 1:2.41 for drydock bergs.

Table 3. Height to draft ratios for pinnacle bergs

	Height (meters)	*Depth (meters)*	*Ratio (1:)*
	16	37	2.31
	59	111	1.88
	32	84	2.62
	34	83	2.44
Mean	35.2	78.8	2.31
S.D.	17.8	30.7	0.32

Table 4. Height to draft ratios for drydocked bergs

	Height (meters)	*Depth (meters)*	*Ratio (1:)*
	53	68	1.28
	44	103	2.34
	30	108	3.60
Mean	42.3	93.0	2.41
S.D.	11.6	21.7	1.16

Domed bergs (weathered, smoothed, deteriorated bergs) were the most deceptive (Table 5). They penetrated the water's depths as the pinnacle bergs penetrated the air. The domed bergs had an average height to depth ratio of 1:6.30, by far the smallest ratio of any class of bergs.

Table 5. Height to draft ratios for domed bergs

	Height (meters)	*Depth (meters)*	*Ratio (1:)*
	30	79	2.63
	16	52	3.25
	12	65	5.42
	21	157	7.48
	13	92	7.07
	9	95	10.56
	12	92	7.67
Mean	16.1	90.3	6.30
S.D.	7.2	33.4	2.76

Conclusion

The assumption was made that the height to draft ratios of icebergs form a continuous distribution. Using a Kruskal-Wallis one-way analysis of variance technique, Welch (1975), the hypothesis that the average ratio for icebergs was not significantly different for the gross visual shape classes was tested. This resulted in the conclusion that, for the sampled icebergs, there was no significant difference between classes. For summary purposes the average of the visual class averages (1:3.95) can be used as descriptive of the height to draft ratio of icebergs regardless of visual shape classes.

Since one visual class was not significantly different from another with respect to the height to draft ratio, all classes were combined and the ratios were plotted against iceberg height. The distribution was by no means linear and was best represented by the power curve (See Figure E-3).

$$1/\text{ratio} = 49.4\ (\text{Height})^{-.8}$$

The taller bergs had a narrower range of height to draft ratios than the lower bergs, which had height to draft ratios which spanned the entire range. Icebergs with the greatest height had the largest height to draft ratios. The draft for tall icebergs was proportionally less than for low bergs. The reasons for this were conjectured to be as follows:

a. The tallest bergs generally had spires and pinnacles which add great height with minimum mass, while the lowest bergs tend to be worn and smooth, having maximum mass for minimum heights.

b. The lowest bergs were worn and have only the most dense ice remaining, all unconsolidated ice and snow having been washed away, and most voids having disappeared causing them to float lower in the water.

The height to draft ratios measured in this study fall generally into three groupings; the horizontal berg, the vertical berg, and the weathered berg. The ratios are smaller (greater depth for a given height) than have been presented in recent work on icebergs. The domed berg has a surprisingly large draft, which must indicate that the underwater portion is not rounded as the top. With these results it will be possible to develop a better model of exactly what water layer is acting on an iceberg during drift and deterioration studies.

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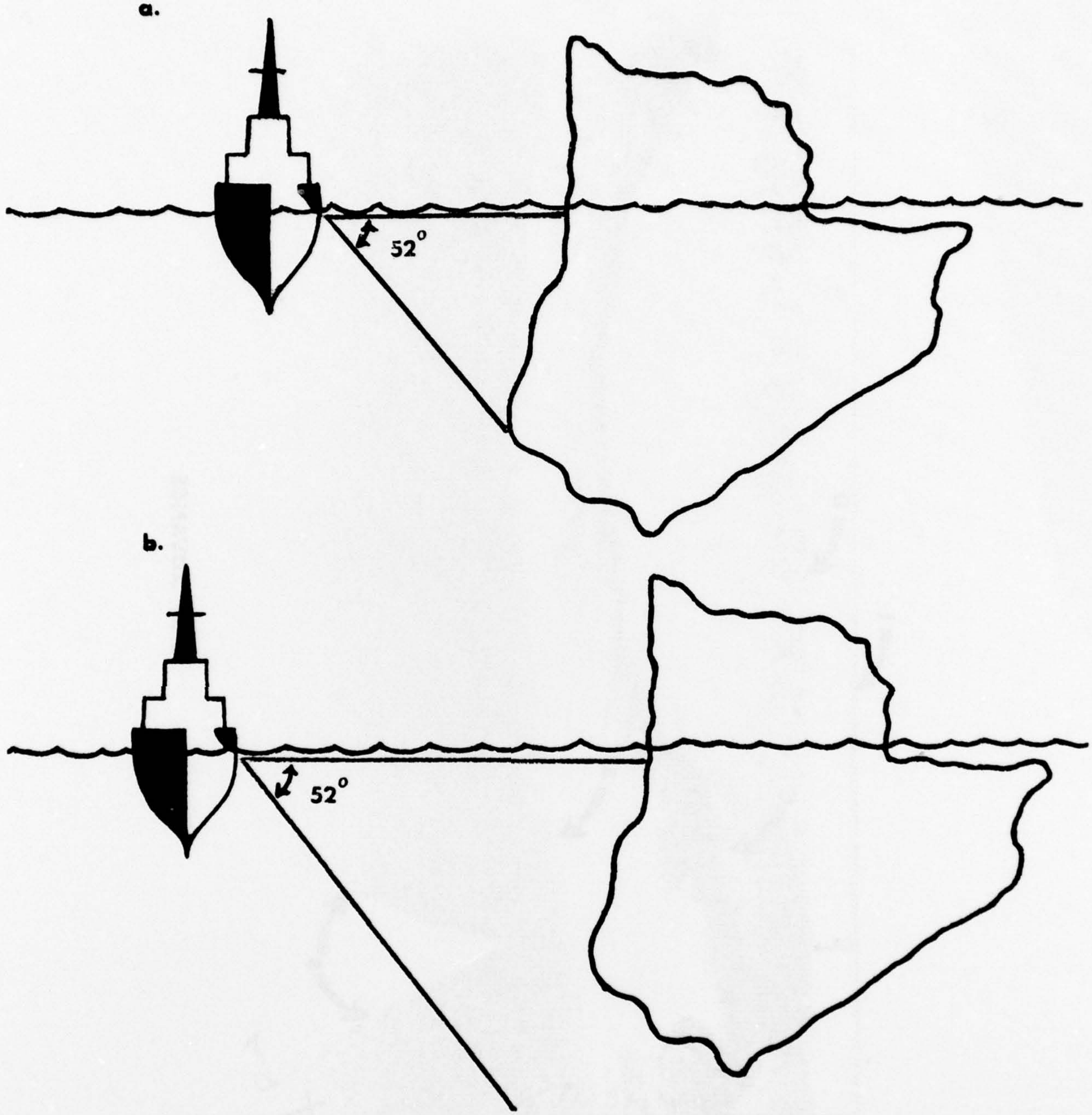

FIGURE E-1.—(a) The beam from a side-looking sonar is completely intercepted by the iceberg at very close range; (b) at great range a portion of the sonar beam will pass under the iceberg and not return to the transducer.

FIGURE E-2.—A sample of the side-looking sonar record showing; (A) the return from the bottom, (B) the shadow of the iceberg on the bottom giving an approximate shape, (C) the return from the iceberg, (D) the return from waves, (E) the zero line on the chart.

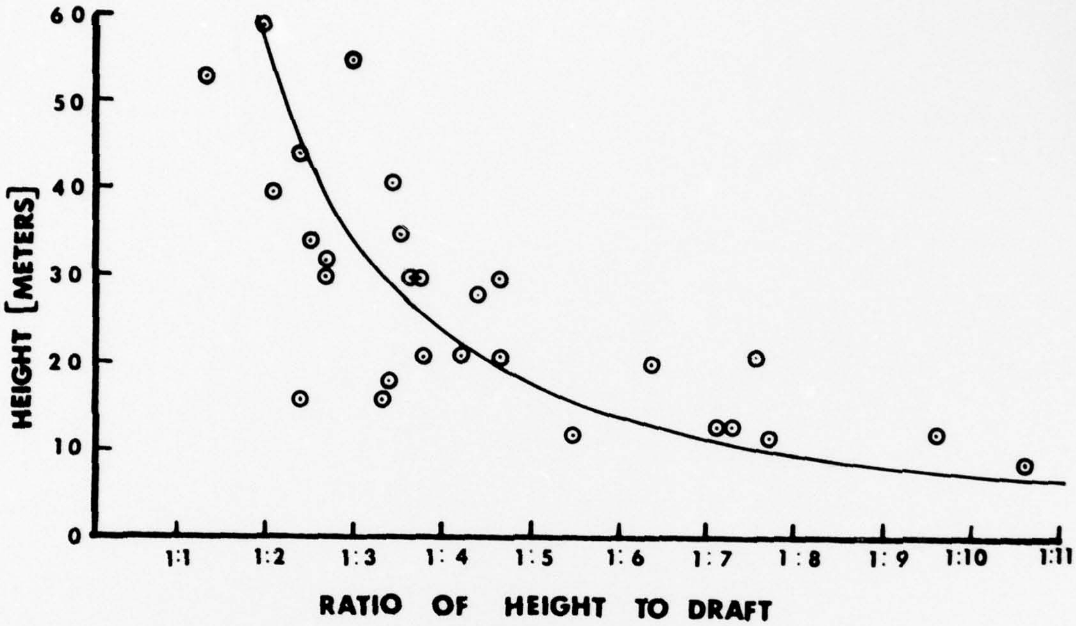

FIGURE E-3.—The distribution of height to draft ratios of icebergs as a function of iceberg height.

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